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FOURTH SERIES
BULLETIN G 6

THE SCENERY OF PENNSYLVANIA

Its Origin and Development based on recent studies of Physiographic and Glacial History

As Interpreted By

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Harrisburg, Pa., May 17, 1933.

Honorable Philip H. Dewey,
Secretary, Department of Internal Affairs,
Harrisburg, Pennsylvania.

My dear Sir:

I have the honor to present herewith a short description and explanation of the surface and scenery of Pennsylvania. It has been written for all interested in that subject, and who is not? It presents briefly the most important findings in this line during the last dozen years. Much of the work has been done voluntarily at little or no cost to the State. It is presented now partly because funds available are insufficient to print either all or any of the eight longer manuscripts on which it has drawn, or any of the mineral resource reports now awaiting publication by the Survey; partly in justice to the geologists who have done the work; but mainly to make available to our people our latest explanation of how the State's surface came to be.

Respectfully submitted,

Geo. H. Ashley

State Geologist.

PREFACE

This bulletin summarizes the results of a number of studies and observations made mostly during the last 13 years. As an outcome of this work our knowledge of the glacial and surface history of Pennsylvania has advanced probably more than in any other similar period. Part of these studies have been made by the Pennsylvania Geological Survey, part by this Survey in cooperation with the U. S. Geological Survey, and part by professors or graduate students in geology with more or less cooperation by the State Survey. Also, a number of studies made independently by others have contributed materially to our knowledge of the subject.

It is planned to publish the results of these special studies as a bulletin, which will contain the following papers:

I. Physiography of the Susquehanna Valley in Pennsylvania, by H. L. Fairchild.

II. Wisconsin drift border and pre-Wisconsin drift and associated gravels in Pennsylvania, by Frank Leverett.

III. Geomorphology of the Wyoming-Lackawanna region, by H. A. Itter.

IV. Recent glacial history of the Delaware Valley below the Water Gap, by Freeman Ward.

V. Terraces of the Susquehanna from Columbia to Lock Haven, with their associated gravels, by Wm. O. Hickok, 4th, and F. T. Moyer.

VI. River terraces in the Susquehanna Valley below Harrisburg, by J. H. Mackin.

VII. Later peneplanes of the Delaware and Susquehanna regions and their associated gravels, by M. R. Campbell and M. N. Shaffner.

As funds for printing are inadequate at this time and there is much uncertainty as to when the bulletin as a whole can be published, it was thought best to prepare and publish this condensed picture of the State's surface and scenery, including the gist of the several papers of the proposed bulletin, with many general observations by the compiler.

Professor Fairchild's study was a labor of love in his spare time in 1921-1923 following the completion of similar studies of the Susquehanna Valley in New York.*

Professor Frank Leverett, who had previously described and mapped the glacial deposits of northwestern Pennsylvania, spent the field seasons of 1926-1928 in a study of the region outside the Wisconsin morainic boundary. This was under a cooperative agreement between the State Survey and the U. S. Geological Survey, of which he was a member. He describes at some length the history of glacial study in Pennsylvania which had resulted in assigning all the glacial deposits of the State to a single glacial advance. Bringing to the task a long and wide experience in the Mississippi Valley, where the evidences for several advances had long been recognized and generally agreed on, he soon

* Fairchild, H. L., The Susquehanna River in New York and evolution of western New York drainage: New York State Mus. Bull., no. 256, 99 pp., 1925.

discovered that the same criteria applied to the deposits in Pennsylvania revealed great differences of age in those deposits, not only in the drift itself, but in the gravels on the river terraces at different elevations.

Since 1930 the lower terraces and gravels on the Susquehanna between Lock Haven and Columbia have been mapped on a scale of 1000 feet to the inch and with 5-foot contours by Messrs. Hickok, Moyer, and Mackin and careful studies made of the character and contents of the gravel deposits. It may also be mentioned that since Professor Fairchild did his work topographic mapping in the region involved has been greatly extended.

Professor Itter's paper on the Wyoming-Lackawanna region is the result of detailed work in 1930, primarily for a doctor's thesis at Columbia University. This work was reviewed by both the writer and Prof. Douglas W. Johnson of the University. Professor Ward's study of the glacial deposits south of Delaware Water Gap was made in 1931 for this Survey. Mr. Campbell of the U. S. Geological Survey has been interested in the physiography of this State for a third of a century and has made many brief field excursions within the State in connection with his general study of the physiography of the Appalachian and Coastal Plain regions. In his recent work in this State, he has been ably assisted by Mr. Shaffner of this Survey. Mr. Shaffner has mapped many of the high-level gravels independently, under the direction of Mr. Campbell or the writer.

Photographs not otherwise credited are by the writer.

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The scenery of Pennsylvania is the result of natural forces acting through hundreds of millions of years. Every feature of the landscape, each river bend, each ravine and hill, each level mountain top, each roll in the valley has a reason. It may be a difference in the hardness or pitch of the rock; it may be the glacial ice paused a moment at that point. Susquehanna Valley at Lanesboro, Pa. Photo by D. S. Harding.

THE SCENERY OF PENNSYLVANIA

By Geo. H. Ashley

INTRODUCTION

Its interest. The earth's surface is always interesting to man. Most men spend all of their lives on the surface, drawing food from its soils, clothing from its plant and animal life, and housing from its trees and rocks. Here man lives and toils. Its rivers facilitate his travel and its mountains interfere with that travel. Its woods and streams make a happy hunting and fishing ground and its lakes and mountains lure him to adventure. The development of his esthetic sense leads him to appreciate and enjoy its scenery.

Its meaning. What he does not always recognize is that every feature of the landscape has a meaning; that is, there is a reason for each bend of a river, for the water gaps, for the mountains being where they are; for one valley being wide, another narrow; for the presence here of a plateau, there of a narrow-crested ridge, for the straight course of this river and the meandering course of that. Learning the meaning of these features is like unraveling the plot of a detective story.

Its variety. Few States have a more pleasing variety of surface and scenery than Pennsylvania. The State lacks very large features, such as broad plains or great mountain ranges, Niagaras, or New River gorges. Its scenery is of the intimate type,—little plains, little mountains, little lakes and waterfalls. All these make up in variety and number what they lack in size. There are wide valleys and narrow, broad plateaus and mountains too narrow crested for even a footpath to follow. In places the rivers seem to have chosen the hardest possible courses, cutting across mountains in deep, narrow gorges when wide open valleys around the mountains exist a few miles either side. Here a waterfall plunges into a dark amphitheater with overhanging walls; there a lake is almost balanced on top of a mountain. In many places broad terraces flank the rivers. The purpose of this paper is to give a better understanding of the origin and meaning of all of these features, in the belief that such an understanding will enhance the pleasure one gets from the surface and scenery of the State as one travels or studies features near home. For that reason illustrations are limited to those showing the surface configuration and do not attempt to present the thousand and one beautiful scenes for which Pennsylvania should be famous.

TYPES OF SCENERY IN PENNSYLVANIA

One of the many reasons for the interest and attractiveness of the scenery of Pennsylvania is its variation from place to place, as no one type is found over all the State. Lakes are found in the northeast and northwest corners of the State, but are lacking elsewhere. Waterfalls occur mostly in the northeast corner. One part of the State consists

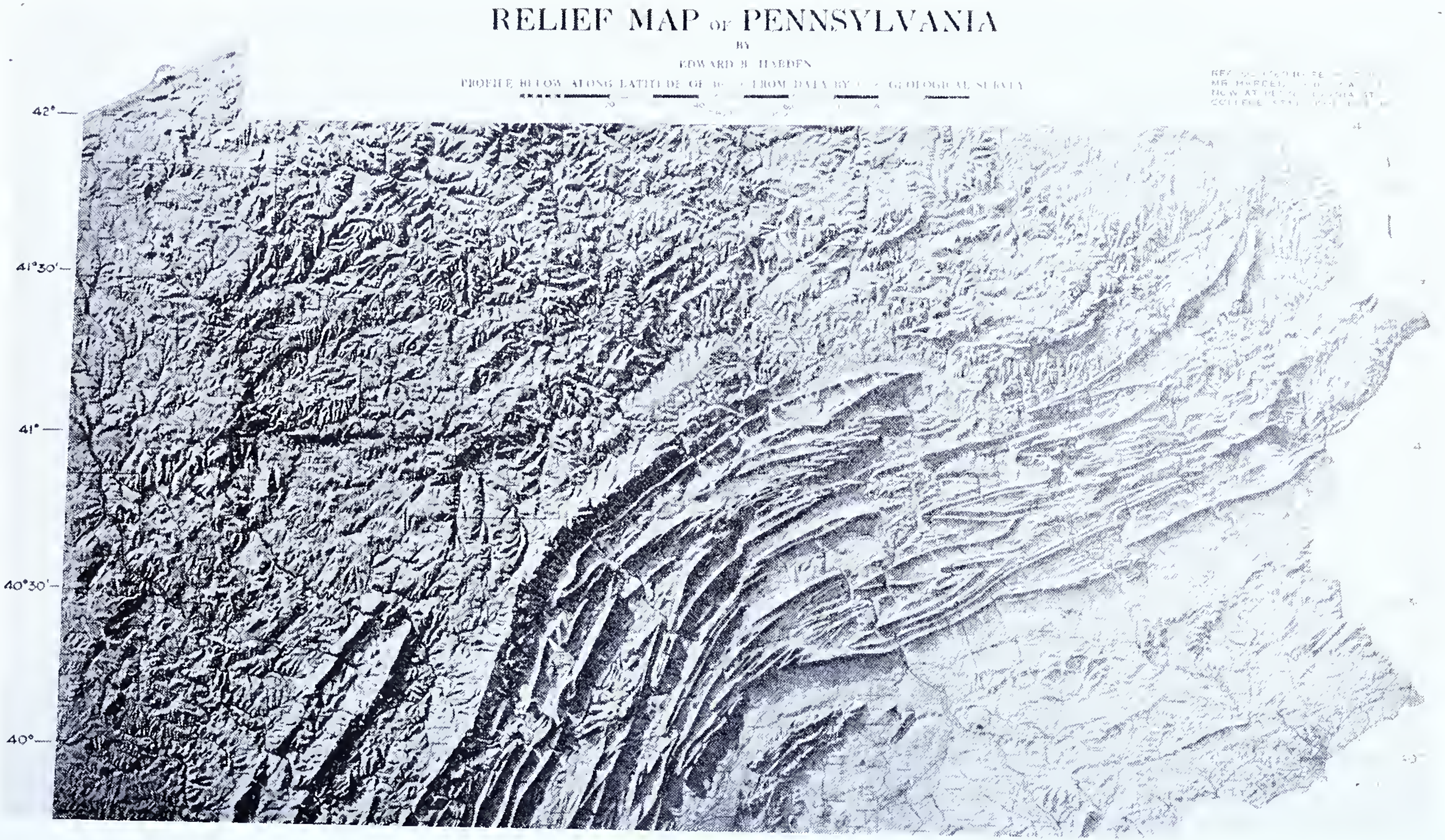

Figure 1. Relief model of Pennsylvania by Edward B. Harden. Original at State College.

of a high, densely-wooded plateau, intercepted by winding mountain gorges 1,000 feet deep. Another part consists of broad parallel valleys separated by narrow mountains, like walled gardens, with water gaps that form gateways from one garden to the next.

The State may be divided into distinct parts or districts, each of which has its own type of scenery which differs from that of any other part. On the other hand most of these types extend far beyond the borders of Pennsylvania, though none of the border States have all these types or so many types as this State. In Erie County are old lake bottoms and shores found nowhere else in the State, a type that is common, however, to the Lake Erie shores, in Ohio and New York. In Delaware, Philadelphia, and Bucks counties is a narrow belt of nearly flat land, typical of the whole Atlantic coastal plain. The Great Smoky Mountains push a finger north into Pennsylvania as the South Mountain of Adams and Franklin counties. The famous Shenandoah Valley is only the southward extension of the less famous but no less beautiful Cumberland, Lebanon, and Lehigh valleys. A tip of the scenery of New England with its Berkshires and Green Mountains finds its way into southeastern Pennsylvania in the Durham and Reading Hills. The lake region of northeastern Pennsylvania is the result of glaciation, as is the lake region that has made central New York famous.

With the coming of good roads, there is no reason why the scenery of Pennsylvania should not become as famous as that of her sister States.

The topography of the State is shown finely by a relief model by Edward E. Harden, a member of the Pennsylvania Second Geological Survey. This model is now at State College.

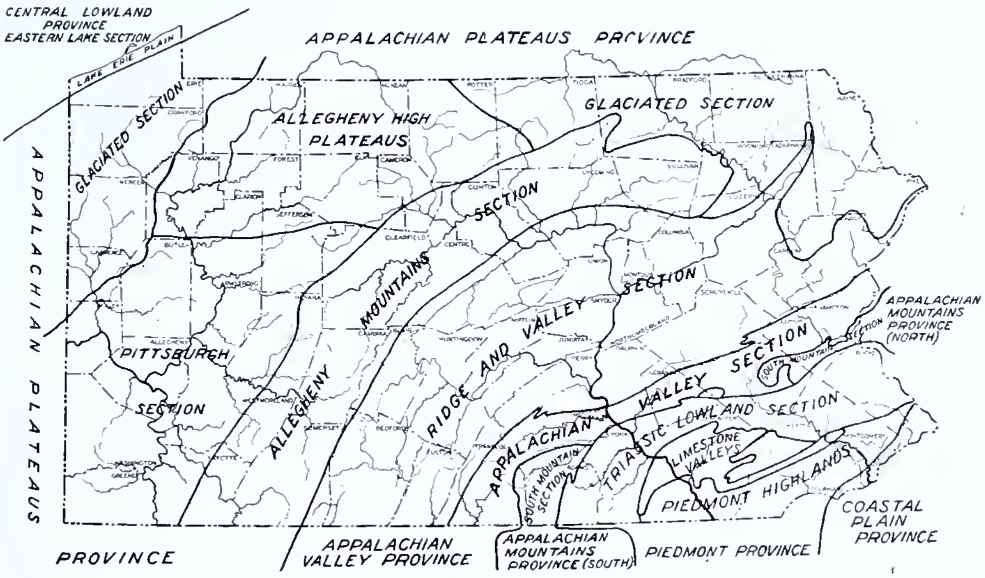

Figure 2. Physiographic subdivisions of Pennsylvania.

The topography of the State falls into six major types as follows: the Central Lowland Province, the Appalachian Plateau Province, the Greater Appalachian Valley Province, the Appalachian Mountains, the Piedmont Province, and the Coastal Plain.

Lake Erie section. This section forms a very narrow belt along the shore of Lake Erie. Physiographically it is distinct and differs from any other section of the State. Its three principal characteristics are: first, the lake bluffs; second, the succession of lake plains rising like steps away from the lake shore; third, a line of "gulfs," narrow, deep ravines formed where streams have sunk their channels through the shoulders of the step-like plains. Figures 3 to 5 show characteristic

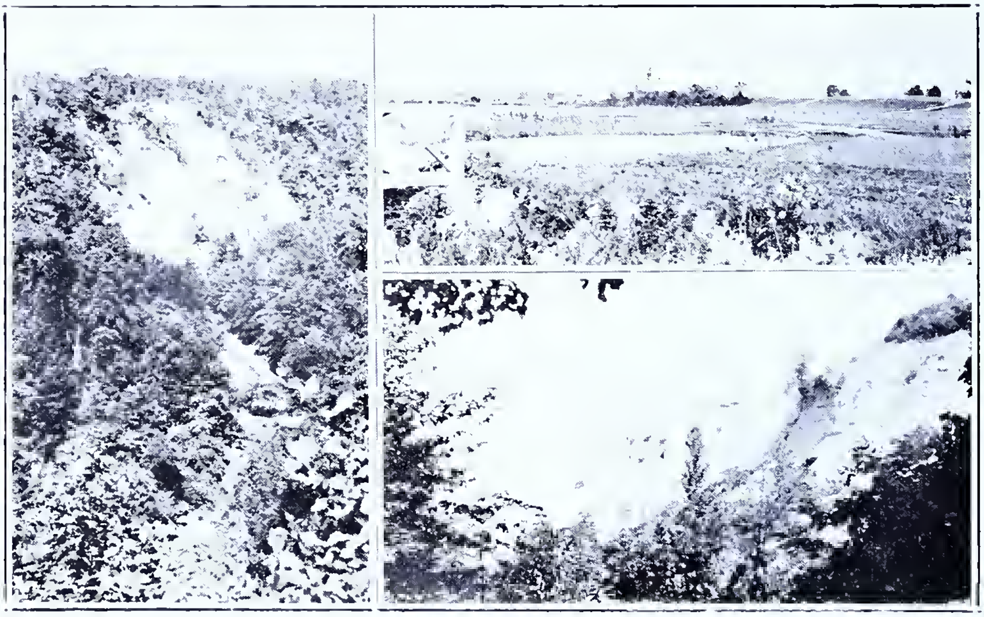

Figure 3. View west of Erie showing bottom of Lake Warren (foreground) and lake shore (background). Upper right view.

Figure 4. Cliff facing Lake Erie, three miles west of Northeast, Erie County. Note Lake Whittlesey sands in upper right hand corner. The gray cliff consists of glacial till. At this point the cliff, which is 180 feet high, results from the lake having eroded all of the Warren beach and cut into the Lake Whittlesey beach. Lower right view.

Figure 5. Wintergreen Gulf on Fourmile Creek, 2½ miles south of Wesleyville, Erie County (on left side).

scenes in this area. The story of how the section came to have its peculiar topography will be told later. As seen today a cross section southward from the lake would have about the profile of a series of broad steps. There may be a cliff 80 to 100 feet high facing the lake, then a broad flat a mile or more wide ending in a sharp rise of 20 to 40 feet, followed by another flat likewise ending in another sharp rise. In western Erie County there are three such flat areas, each of which represents an old lake bottom and shore line. Counting from the lake up, there is Lake Erie, then ancient Lake Warren, Lake Whittlesey, and Lake Maumee. Each of the lake shores may be characterized by sandy beds and even sand dunes. Between Erie and Northeast the present lake has cut back its shore and wiped out all trace of the Lake Warren shore line, making cliffs 180 feet high or more. See Fig. 4. The

"gulfs" add peculiar interest to what might be otherwise a rather drab landscape, as they are cut into this step-like series of plains to a depth of 200 feet or more and have been formed so very recently that their banks are both high and steep. See Fig. 5.

APPALACHIAN PLATEAU PROVINCE

This province covers a broad belt from New York to Alabama between Allegheny Mountain on the east and the Central Lowland on the west. It consists in part of broad plateaus cut by deep narrow ravines; in other parts it is characterized by the general accordance of the hilltops which may or may not be wider than the valleys. These plateaus are at various levels, the highest one now distinctly recognized having an elevation of 2,500 feet in central Pennsylvania and rising to 4,000 feet or more in Kentucky and Tennessee. As shown in Fig. 2, the province is divided into five sections: the Allegheny Mountain section on the east, the High Plateau section at the north, the Pittsburgh section at the southwest, the Western Glaciated section in the northwest, and the Eastern Glaciated section in the northeast part of the State.

Western glaciated section. This section, which lies west of Allegheny River, is characterized in general by gentle topography with broad divides and valleys, several lakes and many swamps, and a peculiar net-like system of interconnecting valleys not now occupied by through streams. This is well illustrated on the Corry and adjacent topographic sheets. See Figure 6. Many of the streams flow in slightly etched channels in broad, flat, bottom lands and head in swamps that may drain either way. In places the surface is uneven or pimply in appearance due to the irregular dumping of glacial material.

The general elevation of the hilltops rises rapidly from west to east from about 1,000 to 1,300 feet above sea level along the Ohio line to 2,000 feet in Warren County. Correspondingly the topography becomes more rugged toward Allegheny River and the valleys deeper though still characteristically interconnected.

Pittsburgh section. West of Chestnut Ridge and more than 1,000 feet lower is a broad area stretching westward in which the hills and stream divides all rise to about the same elevation. The valleys are broadly V-shaped and the divides, at least in southwestern Pennsylvania, broadly A-shaped. The hilltop surface is lowest in the southwestern part of the State in a belt running northwest and southeast through Pittsburgh where it is from 1,200 to 1,400 feet above sea level. Notice the coincidence between this lower elevation and the general direction of the Youghiogheny, Monongahela, Ohio and Beaver rivers. From this lowest area the surface rises to 1,600 feet in the southwest corner of the State and northeastward from Pittsburgh rises with great uniformity to 1,600 feet above sea level in southwestern Venango, Clarion, and Indiana counties. See Fig. 30. The strata rise northward

from Pittsburgh so that in the northern part of this area the more sandy and harder underlying Allegheny and Pottsville formations underlie the hilltop surface, producing broader ridges and correspond-

Figure 6. Part of the topographic map of the Corry quadrangle to show the characteristic drainage topography of that region. Note through valleys with drainage heading in swamps and running both ways.

ingly narrower valleys. To one standing on a hilltop in any of this region the horizon appears like a flat plain as in the prairie lands of the Central States. Throughout this area the river valleys contain what appears to be an old stream system much more meandering than the present system and about 200 feet above the present channels.

Figure 7. Conneaut Lake. Photo by R. W. Stone.

Figure 8. Scene in Greene County typical of the topography of southwestern Pennsylvania. Photo by R. W. Stone.

Allegheny Plateau section. The hilltop surface of the Pittsburgh section continues to rise northeastward, attaining 2,000 feet or more in Warren County. As the hilltops are underlain by resistant sandstones the divides are strikingly broad and level for long distances, as typified by the topography of the Tionesta, Bradford, Blossburg, and Trout Run topographic sheets. Into this broad upland, known as the Allegheny plateau, the streams have cut narrow, winding valleys from 300 to 1,400 feet deep. The plateau area commonly shows two distinct upland levels. The higher levels, covered with timber and

sparsely inhabited, are underlain by two hard sandstones (the Pottsville and Pocono): a lower level 300 to 600 feet below the other and more or less cultivated is underlain by less massive sandstones and shale (Upper Devonian).

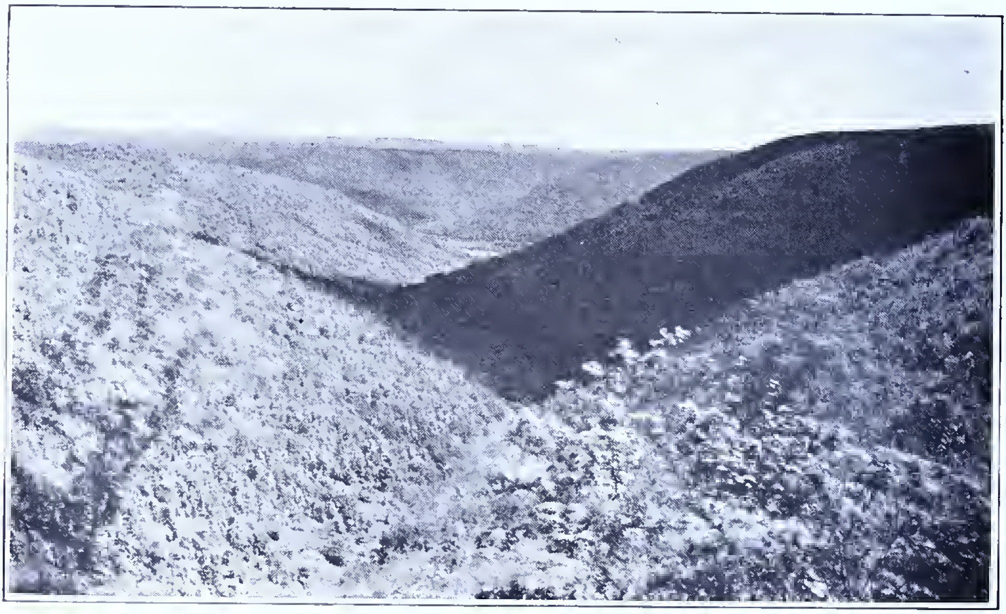

Figure 9. Scene in Potter County typical of much of the high plateau region of northern Pennsylvania. Photo by Pennsylvania Department of Highways.

Allegheny Mountains section. This section is characterized by high mountains, reaching 2,000 feet A. T.* near the North Fork of Susquehanna River, 2,500 feet in the Altoona-Johnstown region, and 3,200 feet in southern Somerset County. At the south the Allegheny Mountains include Allegheny Mountain on the east, Chestnut Ridge on the west, and the high land between, much of which is above 2,500 feet in Somerset County, becoming lower northward. In Clearfield County, Chestnut Ridge loses its steep-sided character and is replaced by a broad upland running across the northern part of the county. (See Fig. 27). Allegheny Mountain breaks down in eastern Centre and Clinton counties, but continues as a line of prominent headlands into Lycoming County, where it again becomes a fairly continuous ridge nearly to Muncy Creek. There the line is carried across Muncy Creek to the south side of North Mountain, which rises to nearly 2,600 feet and may represent an unreduced highland of greater age. Thence the boundary is carried into Wyoming County to the North Fork of the Susquehanna, thence northwest up the river to Towanda. Thence westward, the boundary of the Allegheny Mountains section is between the highlands formed by the Pocono sandstone on the south and the somewhat lower lands formed by the Upper Devonian strata on the north. Figures 10 to 12 give characteristic views in this mountain belt.

* A. T. used often in this paper means above tide.

Figure 10. Plateau upland at 2,000 feet, north of Cresson, Cambria County. This is 500 feet lower than the crest of Allegheny Mountain a few miles to the east.

Figure 11. Typical valley in Allegheny Mountain region. Vanscoyoc Valley north of Tyrone, Blair County.

Figure 12. A river valley through Allegheny Mountain; West Branch of Susquehanna above Lock Haven, Clinton County.

Figure 13. Typical scene in northeastern Pennsylvania. Heart Lake in foreground, near Tompkinsville, Lackawanna County.

Figure 14. Typical glacial lake on mountain top, Eagles Mere, Sullivan County.

Figure 15. Waterfall in Kitchen Creek, Luzerne County. Typical of thousands in the glaciated region of northeastern Pennsylvania.

Eastern glaciated section. The eastern glaciated section differs from the western in its stronger relief, the greater number of lakes, in the smaller number of intercepting valleys and their difference in character, and in the greater variety of its scenery. The Pocono Plateau, for example, is a nearly level highland 1,900 to 2,200 feet A. T., with shallow stream valleys and many lakes. This plateau is underlain by nearly flat-lying, hard Pocono sandstone. East of this highland in Wayne, Pike, and Monroe counties softer rocks have resulted in broad areas of accordant hilltops at a much lower level. The area is made up of irregular rounded hilltops separated by lakes and swamps, and, on the eastern margin, gorges into which the streams plunge from the plateau with numerous waterfalls. These features are well brought out in the topography of the Starrucca, Damascus, Bushkill, and Pocono quadrangles. The combination of hilly upland with its lakes, forests and swamps, the deep intersecting valleys, cool ravines, and the abundance of waterfalls makes this a favorite area for nature lovers.

Figure 16. Part of Damascus topographic map showing characteristic topography of Wayne and Pike counties. Note perched lakes, swamps, low passes between valleys, potato-hill type of topography, etc.

Swinging around the north end of the Northern Anthracite Field the surface changes. The broad uplands with their lakes are replaced with rounded stream divides and the area is minutely subdivided by deep valleys, many with broad bottom lands. The valleys of this area average about 600 feet deep. Lakes are not abundant: some of them are perched on the tops or flanks of hills. This area is dominated by the North Fork of Susquehanna River. Between its westward course below Lanesboro and its southward and eastward course below Sayre the divides have many relatively low gaps between high hills, indicating, as we shall see later, reversals of stream flow.

As elsewhere in the plateau provinces the hilltops are at about the same level and from any hilltop one sees an even horizon, as farther west.

GREATER APPALACHIAN VALLEY PROVINCE

From the escarpment of the Cumberland plateau in Tennessee, one looks across a broad valley to the distant Smoky Montains 50 or 60 miles away. In the valley are many ridges and minor valleys but these are quite subordinate to the high flanking mountains and the great valley itself. The valley changes in character northward and in Pennsylvania consists of two parts: on the west a broad belt of high, narrow mountains separating broad valleys and on the east a much narrower deep-cut valley. To these have been given the names, the Vallemont or Ridge and Valley section and the Appalachian Valley section.

Ridge and Valley or Vallemont section. As shown in Figure 1, this consists of many narrow, even-crested ridges, in general parallel and running from northeast to southwest, but zigzagging or uniting at low angles so as to make a most intricate pattern. These ridges with their many gaps suggest a great labyrinth laid out for the amusement of a child. Even in Figure 1 it is clear that the valleys are broad areas with narrow valleys cut to still lower levels. The ridge tops increase in elevation westward at a fairly uniform rate from 1,300 to 1,600 feet A. T. along Kittatinny Mountain to 2,900 feet on Allegheny Mountain. Not all of the high mountains reach this imaginary surface; many of them lie several hundred feet lower. The broad valleys between the mountains consist in places of broad, flat areas; in others they are interrupted by minor ridges, and some areas are with concordant hilltops. The concordant hilltops occur at levels several hundred feet apart, the lowest, as at Williamsport, lying but little above the present drainage.

A striking feature of this area is the transverse direction of the river valleys and the deep water gaps where they cross the ridges. In places the ridges are so broken with gaps as to resemble a ruined wall (Fig. 1).

Appalachian Valley. Lying between the almost continuous wall of Kittatinny Mountain on the west and north, and the irregular and discontinuous South Mountain on the south and east, is a broad area called the Lehigh, Lebanon, and Cumberland valleys. The continuation of this feature to the south is the Shenandoah Valley or Valley of Virginia, and to the east the Kittatinny Valley of New Jersey, the Wallkill Valley of New York and the Hudson Valley, opening out at

Figure 17. View in Ridge and Valley section showing broad valleys separated by level-crested narrow ridges. Cedar Grove Valley near Mifflintown, Juniata County.

Figure 18. Second Mountain, Dauphin County, formed by resistance of upturned sandstone, flanked by broad valleys eroded out of less resistant shales and sandstone. Photo by Pennsylvania Department of Highways.

the north into the St. Lawrence Valley in Canada. The Appalachian Valley in Pennsylvania also has areas of concordant hilltops at two or three levels. As a rule the northern or western part of the valley underlain by shale or slate is higher and less even than the southern part which is flatter and more fertile.

Figure 19. View near Newville, Cumberland County, characteristic of Appalachian Valley bounded on west by Kittatinny Mountain.

APPALACHIAN MOUNTAINS PROVINCE

In Franklin, Cumberland, and Adams counties is the northern tip of the southern section of the Appalachian Mountains, here known as the South Mountains. These mountains are mostly less than 2,000 feet in elevation, have an uneven sky line, and deep valleys. They end at Dillsburg, but rise again to 1,300 feet near Wernersville, only to disappear across the valley of Schuylkill River and then to reappear on the east side as the Reading Hills. The hills and the low mountains south of Lehigh River extending from Emaus to the Delaware River are the southern end of the northern section of the Appalachian Mountains. These mountains are more picturesque, as a rule, than those farther west, because the massive structure of the rocks gives them a more varied outline and contour.

PIEDMONT PROVINCE

A broad belt underlain by Triassic red beds with many protruding masses of diabase (trap) and extending from Gettysburg to the Delaware in Bucks County constitutes part of the Piedmont Province called the Triassic lowland and hill section. It consists in the main of fairly rounded hills and valleys, mostly under cultivation, but here and there rise knobs, ridges, and conical hills formed by trap rock or by harder sandstones. South of this lies a broad lowland known as the Limestone Valley. Then comes the Piedmont Highlands composed of old schists, gneisses, and other rocks more resistant to erosion than those immediately to the north. As a result of recent uplift this area is dissected by deep, usually narrow valleys, but earlier planation is indicated by the fairly uniform elevation of the hilltops.

Figure 20. Delaware River and canal northwest from Kintersville, Bucks County, crossing highlands of South Mountain.

Figure 21. View at Valley Forge, characteristic of topography in the Triassic hill and lowland section.

Figure 22. Susquehanna River above Holtwood Dam, characteristic of the river gorge through the Piedmont Upland section.

Along the Delaware is a narrow belt of land close to sea level, composed largely of sands and silts laid down during recent submergence of the present Delaware Valley. Philadelphia lies in this belt.

This province extends up to Trenton and Yardley.

ORIGIN OF THE PENNSYLVANIA SCENERY IN OUTLINE

It is the purpose of this paper to discuss the very clear and definite reasons for these differences in the scenery of the several parts of the State.

The present surface of Pennsylvania is almost entirely the work of water carving or dissolving rocks of different hardness or durability and lying at different angles. While this erosion was going on the rocks were slowly and intermittently being raised higher and higher above sea level.

On the other hand these differences of surface form often serve as a key to many past events. The swamp of today, formerly a lake, records where the glacial ice stopped and slid some of its rock load off its shoulders, damming up a former valley. The level tops of the ridges and plateaus tell of a time long ago when they were part of a plain lying but little above sea level and of subsequent elevation. A wind gap tells of a time when it was part of a valley, whose stream was captured by a robber stream and the valley abandoned.

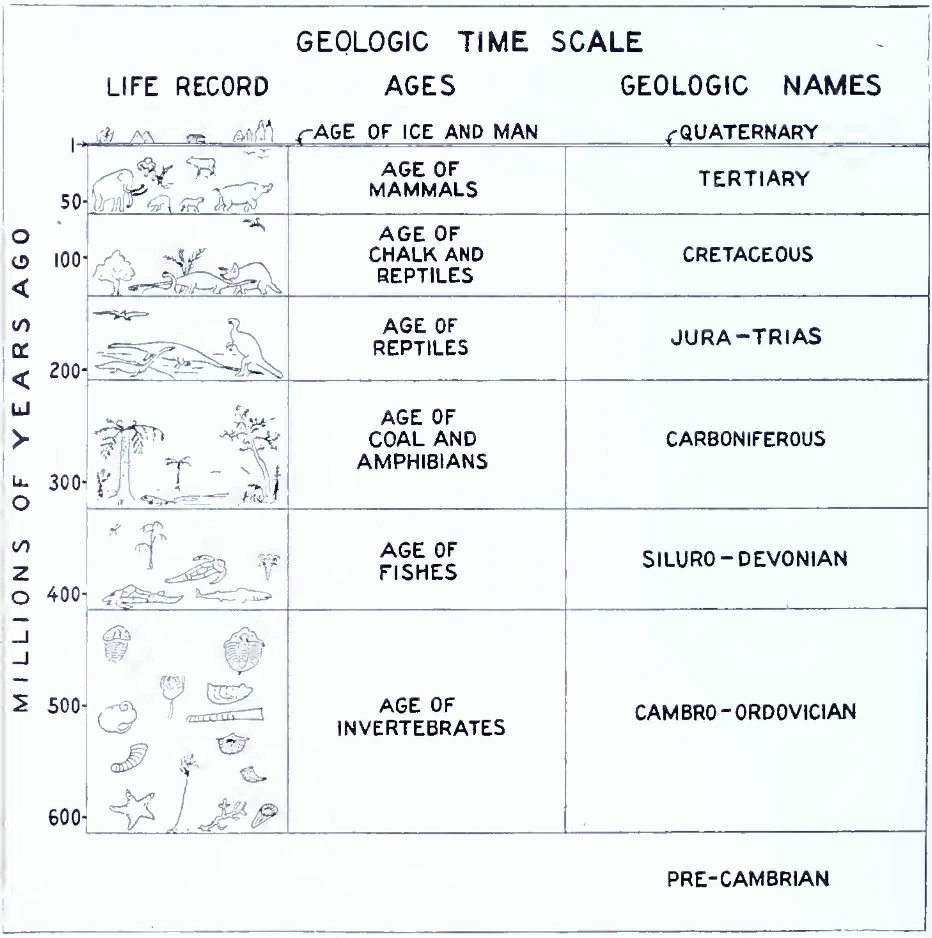

Figure 23. Geologic time chart.

The geologic story. In order to understand how rocks of different hardness or durability came to be standing at different angles and to have determined the surface and scenery of today, it is necessary to go back many years and review in a few words the geologic history of Pennsylvania. The story is more fully told in the Survey's Bulletin G-1, A Syllabus of Pennsylvania Geology and Mineral Resources.

Figure 23 shows graphically the larger time divisions of the past, stretching back 600 million years. At the left are examples of the unfolding life of the several geologic ages. This will serve as a basis for timing the events in Figure 24.

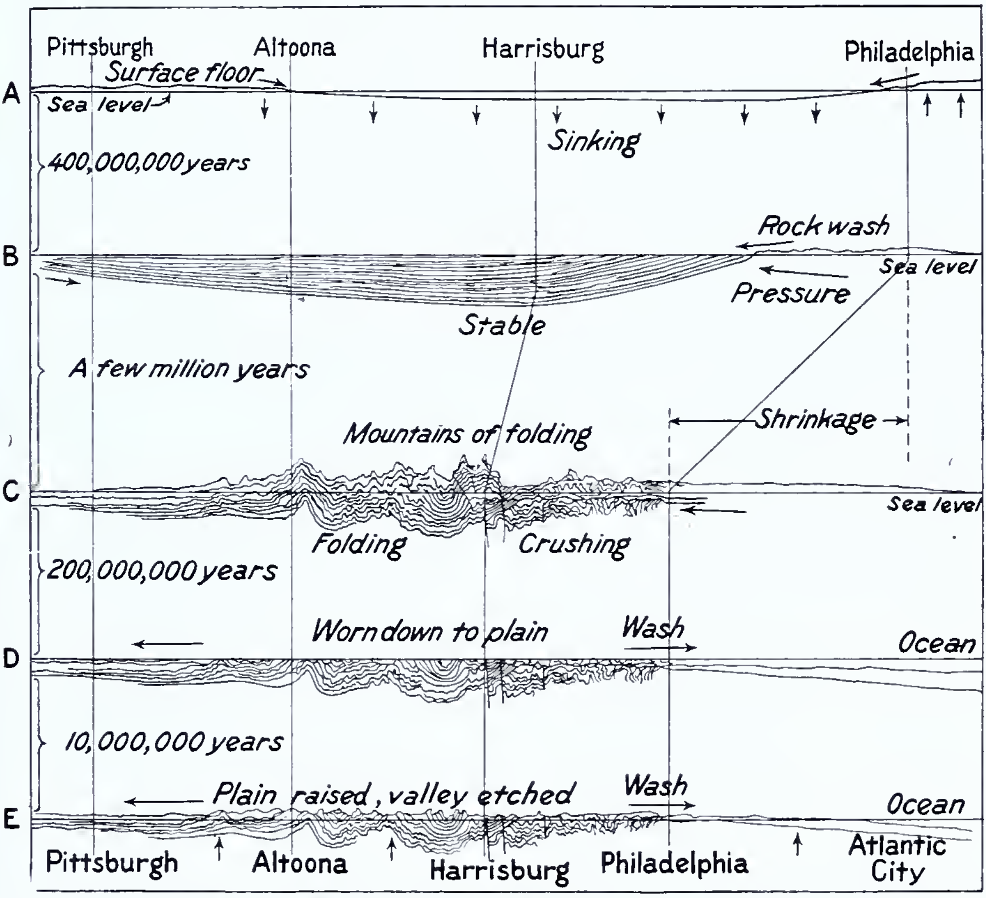

Figure. 24. Chart showing principal events in the geologic development of Pennsylvania.

The early chapters. The rocks of southeastern Pennsylvania reveal two very early chapters, during each of which thousands of feet of sediments were laid down in the sea, consolidated into rock, folded up into mountains, and then worn down to a plane. That occurred between one billion and 600 million years ago. About 600 million years ago eastern Pennsylvania was part of an inland sea (Fig. 24-A) into which sediments—muds, sands, gravels, and limy materials—were being washed, mainly from the southeast. The sea bottom rose and sank as time passed, but in the main sinking dominated and ultimately reached so great a depth that 30,000 feet of rock material had accumulated in southeastern Pennsylvania, but thinning to half of that or less in northwestern Pennsylvania. (Fig. 24-B). Pressure due to the

weight of the overlying layers, and the action of water, changed to rock these sediments, sands to sandstone, gravels to conglomerate, muds to shale, and limy deposits to limestone. These were the rocks that later, folded up and worn down, were to determine the character of the surface of most of the State. They were accumulated during the first three ages shown on the time chart, that is from the invertebrates to the amphibians inclusive. Massive sandstones that later became mountain-makers were laid down at the base of the Cambrian (Chickies quartzite), the Silurian (Medina or Tuscarora quartzite), the Carboniferous (Pocono sandstone), and at the base of the mid-Carboniferous (Pottsville sandstone). In the main, the other rocks are shaly or limy and underlie and are responsible for the valleys.

The Appalachian revolution. At the end of the Carboniferous age, this great body of newly formed rocks was subjected to pressure from the southeast and folded or crushed, as when a pile of rugs spread out on the floor is pushed from one end. In the eastern part of the State, the rocks were pushed westward, shortening the rocks now underlying the State by one or two hundred miles, and the folds are believed to have projected high in the air as mountains, possibly comparable with the Alps or Andes of today (Fig. 24-C).

The great erosion. Then came the age of reptiles and the earlier half of the age of mammals, during which time the mountains were wearing down to a plane but little above sea level (Fig. 24-D). Many things happened during that time. At one time (Upper Triassic) great breaks in the earth's crust allowed a belt extending from New England to North Carolina to sink. Into this sunken area sediments washed as sinking progressed until over 20,000 feet of red sandstone and shales had accumulated. At the same time great bodies of molten rock (trap) welled up through the earth's crust.

It is now thought that between the conditions illustrated in Fig. 24, C and D, the rocks were worn down to a plane several times. After each time came slight uplift and the wearing down of the surface to a new and lower plane. It is also believed that the eastern and possibly the central part of the State sank below sea level a number of times, and sediments corresponding to the shoreward edge of those now found in New Jersey were deposited over the submerged surface. With each succeeding uplift of the land these sediments would be carried away and the underlying rock etched into valleys and ultimately reduced to a new plane.

THE PENEPLANES OF PENNSYLVANIA*

*Schooley peneplane.*** It is now thought that one of the last of these planes is reflected in the tops of many mountains in the State. Anyone looking off from the top of any of the higher mountains will observe that the other mountains in sight are commonly flat-topped as shown in Figure 25.

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* Peneplane means almost a plane, and refers to a plane formed by long continued erosion, usually but little above sea level. It commonly is applied to planes no longer existing but indicated by the existence of concordant hilltops, water gaps, or other evidence.

** Davis, Wm. M., The rivers and valleys of Pennsylvania; Nat. Geog. Mag. vol. 1, 183-253, 1889.

Campbell, M. R., Geographic development of northern Pennsylvania and southern New York.

The final stage in the making of the scenery of most of Pennsylvania has been the result of a succession of broad uplifts with long stops between the several uplifts, and the gradual wearing down of the softer rocks into valleys. Each stop was recorded by the development of a partial plane or peneplane. The most prominent of these in order are: Schooley, Allegheny (Chambersburg?), Harrisburg, and Somerville.

Figure 25. View west from Tuscarora Mountain at Lincoln Highway showing trace of Schooley peneplane by level-topped mountains in distance. Valley in middle ground characteristic of younger peneplane.

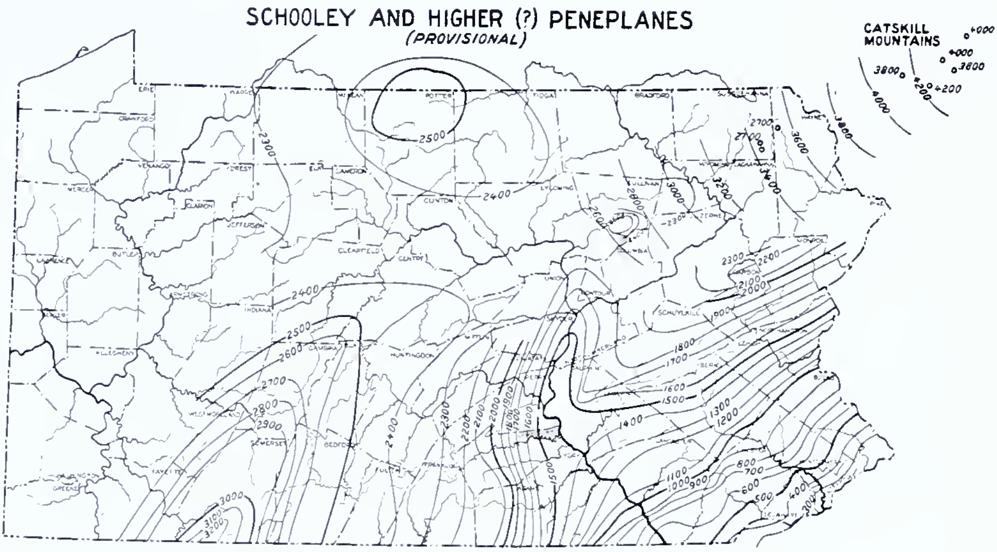

Figure 26. Chart showing by hypothetic contours present position of the deformed Schooley peneplane and possibly an older peneplane from North Mountain to the Catskills. The contours are those of the present "hilltop surface," not a higher hypothetical surface.

The Schooley peneplane can be traced in southern Pennsylvania with a fair degree of definiteness, as indicated in Figure 26. The surface shown by the contours is such as would be formed if all of the valleys were filled level with the highest mountain tops. It appears to rise northward and westward, from about 300 feet A. T. near Philadelphia to 3,200 feet in southern Somerset County. The crest rises to 4,000 feet in West Virginia, but appears to decline to 2,500 feet in southern Clearfield County. Peneplanes are traced mostly by means of topographic maps. Such maps are still lacking in most of northern Pennsylvania. The mountain tops in the part of northern Pennsylvania now mapped present such a diversity of elevations that much doubt exists as to which levels belong to which plane. The highest hilltops in Clearfield, Centre, Clinton, and Lycoming counties decline from 2,500 feet A. T. in southern Clearfield County to 2,200-2,300 feet in

Figure 27. View from fire tower in northern Clearfield County showing Schooley peneplane where well preserved.

Figure 27-A. Crest of North Mountain, from fire tower west of Kitchen Creek, showing evidence of peneplanation.

northern Clearfield, Centre, and Clinton counties, to 2,300 feet in northern Lycoming or 2,000 feet in southern Lycoming County. In most of Sullivan County the hilltops are between 2,000 and 2,200 feet above sea level, but in the southern part of the county North Mountain rises to 2,600 feet with concordant crests that suggest an old plane. See figure 27A. The Elk Hills in southeastern Susquehanna County rise to 2,700 feet. The Catskills in New York present concordant peaks at 4,000-4,200 feet, and the tops of the Adirondacks are also concordant at 4,900 to 5,300 feet.

North Mountain in Sullivan County and the crests of the Catskills and Adirondacks may represent parts of a single peneplane, much older than the Schooley, or it may be that the sublevel areas of northeastern Pennsylvania, between 2,300 and 2,400 feet, represent an erosion surface younger than the Schooley, and that if the Schooley surface were completely restored it would rise above North Mountain, the Catskills, and the Adirondacks. This is suggested, though not proved, by the theoretical drainage of the early headwaters of the Susquehanna.

Figure 28. View north from Harrisburg; shows gaps through Kittatinny and Second Mountains and behind, the level crest of Peters or Cove Mountain.

The problem of whether the present mountain tops reveal traces of one or two peneplanes has been studied for some time. Those holding that there were two planes of slightly different age have called the higher (or older?) the Kittatinny. The area north of Harrisburg has sometimes been cited as exhibiting the two surfaces. North of Harrisburg a number of parallel ridges, including Kittatinny or North, Second, Third, Peters, Berry, Buffalo, Mahantango and other mountains, show remarkably level crests at about 1,300 to 1,400 feet A. T. Taking account of the level character of these crests and the fact that three separate sandstones enter into their formation it would seem to be a logical conclusion that a peneplane had formerly existed a short distance above the present crests of these mountains. However, eastward a few miles Third Mountain broadens and rises to 1,660 feet. It displays a broad flat top at that level, an elevation that is continued eastward in the summits of Stony and Sharp mountains as though representing a remnant of a higher and older plain. So too, Broad Mountain and Short Mountain farther to the north, and the east end of Peters Mountain, rise and maintain their crests between 1,600 and 1,700 feet A. T. But in each of these instances the higher mountains

are associated with structural features which give greater breadth to the mountain-forming sandstone at any given elevation than is found in the lower crests previously cited. This great breadth would seem to present a reason for the higher elevation, assuming that both these higher crests and the lower crests had descended from a common peneplane. Similar diversity of elevations is found in other places and it is these conditions that led to the idea of two peneplanes.

A cross section through Schooley and Kittatinny mountains, however, shows that the crest of Kittatinny Mountain near Delaware Water Gap lies almost exactly in a ruler line between the crest of Pocono Mountain and the crest of Schooley Mountain. From Pocono Mountain (1,900 feet A. T.) to Kittatinny Mountain (1,600 feet) is about 12 miles. A line joining the two crests has a fall of 25 feet to the mile. Schooley Mountain (1,000 to 1,200 feet, average 1,100 feet) is 20 miles east of Kittatinny Mountain and the fall in the line between these two crests also is 25 feet per mile. Ten miles farther southeast the crest of Cushetunk Mountain (860 feet) gives a further fall of 24 feet per mile. General contour lines on a hypothetical, restored hilltop surface from the bluffs at 450 feet A. T. facing the Delaware at Trenton to the southeast face of the Pocono plateau are remarkably uniform in their spacing and strongly suggest reduction from a single surface. If therefore, there are traces of two peneplanes in the present mountain tops of Pennsylvania, some other name than Kittatinny must be used for the second plane, as it is younger rather than older than the Schooley.

The writer has concluded:

(1) That certain high points, such as Elk Hills in Susquehanna County, North Mountain in Sullivan County, and Blue Knob in Bedford County, probably represent unreduced high lands that projected above the Schooley peneplane..

(2) That probably one or more older (now higher if restored) peneplanes have existed in Pennsylvania of which there is now no trace in this State unless concordant tops of North Mountain in Sullivan County and of the Catskills in New York represent such a trace.

(3) That following the uplift of the Schooley peneplane, while the valley areas have been lowered 600 to 800 feet more than the mountain tops, all of the mountain tops have also been lowered by an amount to be measured in hundreds rather than in scores of feet, as commonly inferred, if not stated. The fact that the highest crests commonly occur where thickness of rocks, low dip, back folding, or other conditions seem to offer a reasonable explanation for retarded erosion, leads to the suggestion that the two or more sets of levels of the mountain tops are the result of differing resistance to downcutting from a single plain. This calls for further study; but a little travel on top of some of these narrow-crested ridges must convince anyone that they are being cut down with relative rapidity.

(4) That the uplifted Schooley peneplane, if restored today uneroded, would show an irregular rolling surface possibly with fault scarp faces where there had been subsequent crustal breaking and displacement.

Whether the deep embayment up the Susquehanna Valley is due to warping or to subsequent erosion is not certain. Also it is uncertain whether the differences of elevation on the Pocono sandstone and the Upper Devonian rocks of north central Pennsylvania, (see Blossburg and Trout Run topographic sheets) are due to differential erosion or represent two peneplane surfaces. The striking accordance of the hilltops of the lower surface, as with the accordance of the hilltops north of Harrisburg, seems to point to peneplanation.

As to the age of the Schooley peneplane; until recently it has been assumed to be pre-Cretaceous in age.[1] By contrast the writer[2] has contended that this peneplane was not older than middle Tertiary. Among several lines of evidence presented may be mentioned the fact that, as noted above, the Schooley peneplane in eastern Pennsylvania and New Jersey has a present inclination of about 25 feet to the mile, as contrasted with about 75 feet to the mile for the surface underlying the Cretaceous of New Jersey or Maryland. The Kirkwood formation of New Jersey, on the other hand, lies on a surface with a southeastward inclination of 32.6 feet per mile as measured from Ashland, N. J. where it is 80 feet A. T. and Atlantic City, 40 miles southeast, where it is 1,225 feet below tide. The slight difference might be owing to deformation or to erosion of the exposed surface.

Studies made since this paper went to press have strengthened the suspicion that the Schooley peneplane would, if restored, rise high over northern Pennsylvania and New York, overtopping North Mountain, the Elk Hills, as well as the Catskills and Adirondacks of New York State, and that the variation in the elevations of level areas in northern Pennsylvania is probably due to differential erosion.

Intermediate cycles of erosion. In addition to the other peneplanes noted here some geologists have identified several other erosion planes. Among these are the Mine Ridge and Honeybrook.[3] Other geologists, however, feel that the evidence so far presented is too meager and local to establish these surfaces as of peneplane order.

Allegheny (Sunbury-Chambersburg ?) peneplane. From 250 to 1,500 feet below the hilltop trace of the Schooley plane there is the trace of a plane representing a standstill so long that in western Pennsylvania (west of Chestnut Ridge) all trace of the Schooley plane was destroyed. The level-topped hills of western Pennsylvania, which in Westmoreland County are 1,400-1,500 feet below the crest of Chestnut Ridge, reveal this later plane. This has been called by the writer the Allegheny peneplane from its fine development in the Allegheny River region of Venango and Forest counties. From any high point in western Pennsylvania the distant horizon appears as level as a prairie or as the horizon at sea. This plane was formerly called the Harrisburg peneplane; but the hilltop trace of a plane at Harrisburg is now thought to be younger.

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[1] See for example: Stose, G. W., High gravels of Susquehanna River above Columbia, Pennsylvania: Bull. Geol. Soc. of Am., vol. 39, pp. 1073-1086, Dec. 30, 1928.

[2] Ashley, Geo. H., Age of the Appalachian peneplains. Bull. Geol. Soc. of Am., vol. 41, pp. 695-700, 1930.

[3] Bascom, F., Cycles of erosion in the Piedmont Province of Pennsylvania: Jour. of Geol., vol. XXIX, no. 6, 1921.

Knopf, Eleanora Bliss, Correlation of residual erosion surfaces in the eastern Appalachian Highland: Bull. Geol. Soc. of Am., vol. 35, pp. 633-666, 1924.

Figure 29. View in Jefferson County showing level horizon characteristic of Allegheny peneplane in western Pennsylvania. In this area the lack of any resistant sandstone above water level results in broad valleys largely under cultivation. Photo by Pennsylvania Department of Highways.

As preserved today in western Pennsylvania, this hilltop plane forms a broad basin with a northwest-southeast axis, following about the line of the Youghiogheny, Monongahela, Ohio, and Beaver rivers. At the center it is less than 1,400 feet above sea level, most of the hills rising only to 1,250 or 1,300 feet. It rises to 1,600 feet in the southwest corner of the State, and northward to 2,000 feet in Warren County, and may be represented by the hilltops at 2,200 to 2,300 feet in the Bradford region.

In the eastern part of the State what may be the same peneplane has been called the Sunbury.[4] More recently it has been called by

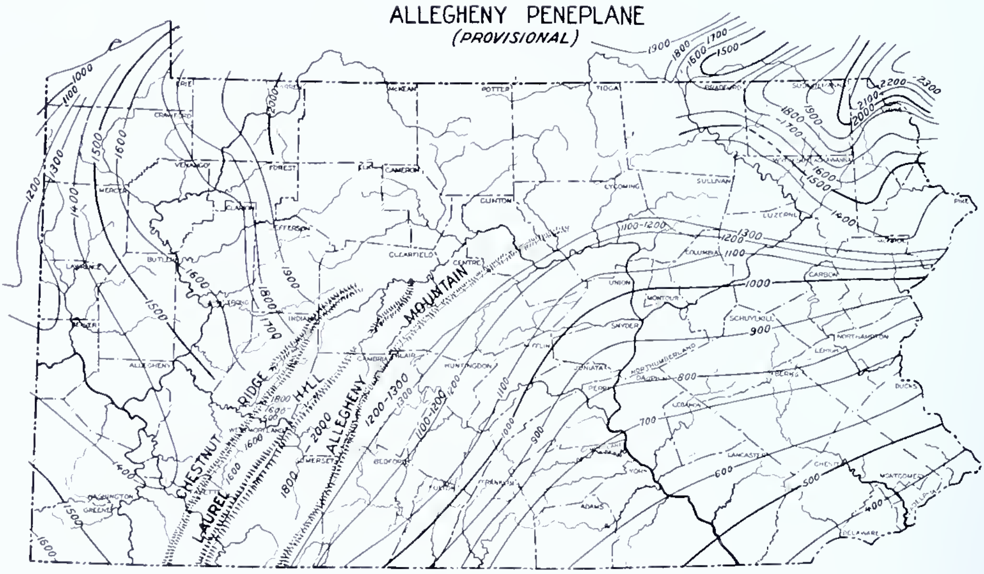


Figure 30. Sketch map of Pennsylvania showing by contours the elevations of hilltops correlated with the Allegheny peneplane in the west, or the Sunbury-Chambersburg peneplane in the east. The higher elevations between Chestnut Ridge and Laurel Hill and between Laurel Hill and Allegheny Mountain are thought to be of the same age, but held up by hard rocks in the gaps of Laurel Hill and Chestnut Ridge that retarded erosion.

[4] Barrell, Joseph; Am. Jour. of Sci., vol. 49, p. 336, 1920.

Campbell[5] the Chambersburg peneplane (to distinguish it from the later Harrisburg), from the level-topped hill at 750 feet A. T. just west of Chambersburg. It rises from about 600 feet at Hanover to about 1,300 feet in the valleys south and east of Allegheny Mountain from Bedford County to Lycoming County. It forms a pronounced terrace up the Potomac River and its tributary valleys, rising from about 500 feet in southeastern York County or 650 feet at Harpers Ferry, to 940 feet west of Hancock, 1,100 feet at Cumberland, and 1,200-1,300 feet just east of Allegheny Mountain. This plane is thought to coincide with the hilltops of many of the valleys of central Pennsylvania.

In the Delaware River region this plane appears to rise from 400 feet in southern Bucks County to 1,300 feet in southern Pike County, to 1,800 or 1,900 feet in Wayne County, and possibly corresponds with the hilltops at 2,000 to 2,300 feet in New York west of the Catskills. In southern New York it forms a distinct northeast-southwest basin following in a general way the course of the headwaters of the Susquehanna. It has an elevation of about 1,500 feet just north of eastern Bradford County and rises to 2,000 feet north of Wayne County and to 2,000 feet northwest of the center of the basin in Tompkins and Cortland counties, New York. The figures for southern New York and northern Pennsylvania are tentative until there is opportunity to study the areas not yet mapped topographically and to study these elevations in the field.

In correlating the Allegheny and Chambersburg peneplanes it should be distinctly noted that it has not yet been proven that they are the same. First, direct tracing from one to the other across the Allegheny Mountains or around those mountains has not been made, and such a tracing presents difficulties. Second, west of the Allegheny Mountains the Allegheny peneplane presents what appears to be a deformed surface with a low point of 1,400 feet A. T. or less, about where Youghiogheny River emerges from Chestnut Ridge and rising northward to southeastern Jefferson County and Clearfield County. No corresponding deformation of the Chambersburg peneplane east of the mountains has been discovered. On the contrary the pronounced peneplane (Allegheny) of northwestern and central Clearfield County at 1,900 feet is in strong contrast with the elevations east of the mountains correlated with the Chambersburg and only a few miles away, which has elevations of from 1,200 to 1,400 feet.

It may later prove that the differences of elevation of the Allegheny peneplane are not due to deformation but are the result of differential erosion on rocks of different hardness combined with the dip of the harder rocks, such as the Pottsville conglomerate, which forms much of the surface of the peneplane. This theory would account for the lack of any corresponding deformation in the earlier Schooley peneplane in the Allegheny Mountain area, for it would seem that the earlier peneplanes should share in any later crustal movements such as would be necessary to have deformed the plane on the west.

In this connection note the parallelism between the crest of Allegheny Mountain and the hills cut in the Upper Devonian rocks immediately east or south of that mountain, as indicated in the following table:

[5] Campbell, M. R., Chambersburg (Harrisburg) peneplain in the Piedmont of Maryland and Pennsylvania: Bull. Geol. Soc. of Am., vol. 44, pp. 553-573, June 30, 1933.

ELEVATION ON AND NEAR ALLEGHENY MOUNTAIN

Near	*On Allegheny Mountain* *Feet*	*Foothills* *Feet*	*Difference* *Feet*
State Line	2,950	2,150	800
Southern Cambria County line	2,750	2,000	750
Altoona	2,500	1,700	800
Bellefonte	2,200	1,500	700
North of Williamsport	1,900	1,200	700
Muncy	2,000	1,300	700

The lower surface in the Muncy-Williamsport area, which is about 6 miles wide, has been thought to correlate with the Chambersburg peneplane; but as just traced to the southern State line it rises to over

Figures 30-A and-B. Sketch maps of type locality of Harrisburg peneplane. The crosslined area shows the hilltops lying between 500 and 560 feet above tide and thought to reflect an erosion plane originally a little above that surface. The white part of the map represents surface below 500 feet, and the black, surface above 560 feet. The meanders of the streams are thought to have been established on either the Harrisburg or Chambersburg peneplane. These streams head in shallow valleys in plains but near their mouths are incised to a depth of 200 feet or more.

2,000 feet at that point, while the Chambersburg peneplane as traced by Campbell up the Potomac Valley has an elevation of only 1,000 feet in southeastern Bedford County, and probably not over 1,200 to 1,300 feet immediately east of Allegheny Mountain in south Bedford County, and to correspond with broad areas at that level in Bedford, Blair, and Centre counties.

Harrisburg and Somerville peneplanes. Below the last peneplane are apparently two fairly widespread peneplanes, though in many areas they are represented only by river terraces. They represent two periods of standstill in the slow uplifting of the earth's crust in Pennsylvania and elsewhere. The higher of these, which is well displayed in the concordant hilltops of the Lebanon and Cumberland valleys, has been called the Harrisburg peneplane. Near Harrisburg it lies from 220 to 250 feet above the river. It is believed to correspond to the broad, flat divide between Conewago Creek and the head of Rock

Figure 31. Erosion plane northeast of Gettysburg, seen from Pigeon Hills, showing characteristic flat surface of Harrisburg or Chambersburg peneplane at the head of drainage where little eroded. Photo by R. W. Stone.

Creek northeast of Gettysburg (See Figure 30B); to hilltops at 500-600 feet A. T. at Millerstown and Millersburg; 600 feet on the Juniata at Lewistown; 700 feet in Ferguson Valley; 800-900 feet in Kishacoquillas Valley.

The hilltops in White Deer Valley, west of Montgomery, at about 700 feet A. T. in Union and southern Lycoming County are thought to belong to this period of standstill. It is thought that this peneplane corresponds in western Pennsylvania with the Worthington peneplane of the Allegheny Valley, a plane described by Charles Butts in the Kittanning region to account for accordant hilltops below the level of the principal hilltop plane.

The Somerville peneplane is most strikingly displayed in Northampton County, in the broad, flat area lying north of Lehigh River between Allentown and Easton (see Allentown topographic map). It

Figure 32. Valley upland correlated with the level of the Harrisburg peneplane. Kishacoquillas Valley northwest of Reedsville, Mifflin County.

is represented by other broad, flat areas in New Jersey which decline from 400 feet at Easton to 100 feet A. T. a little southeast of Somerville, N. J. West of Allentown it is correlated with the broad uplands at about 400 feet A. T. in the limestone areas of Lebanon and Cumberland valleys. In the Susquehanna area this peneplane is represented mainly by broad, flat areas in limestone at 420-440 feet A. T., (or at about 120-140 feet above the river in the Harrisburg region), 500 feet at Sunbury and Selinsgrove, reaching 540 to 580 feet at Muncy, 540 feet at Lewistown on the Juniata, 640 feet at Mt. Union.

Figure 33. White Deer Valley looking toward White Deer Mountain from two miles northeast of Elimsport, thought to represent the Harrisburg peneplane. Photo by H. L. Fairchild.

South of Harrisburg, in the physiographic "Limestone Valleys" section, so widespread in Lancaster County, the broad, level areas continue at about 400 feet A. T. as though in that area the Somerville had been uplifted without deformation. In this respect the Harrisburg peneplane trace seems to run parallel to that of the Somerville; that is, hilltops in the Conewago Valley near Manchester, in the York Valley near Wrightsville, and in the Lancaster Valley, as at Creswell, Conestoga, Sporting Hill, Brunnerville, Kisselhill, and elsewhere maintain elevations at 500-540 feet A. T. as though this surface had not been deformed in that area between Kittatinny Mountain on the north and the Piedmont Highland on the south, and therefore are in accord with the flat terraces reported by Campbell as found on Schuylkill River between Pottsville and Pottstown.

The Somerville peneplane is thought to date a little before the time of the Illinoian ice advance. Careful surveys at Harrisburg, as pointed out by Hickok, show that the top of the gravel terrace of supposed Illinoian age is at least 20 feet below the rock flats of supposed Somerville age, and that the rock terraces on which these gravels occur have been cut to 50 or 60 feet below the Somerville erosion surface, or to about half way from the level of the Somerville plane to the present river bed. If the Illinoian ice retreated 150,000 years ago, as Leverett suggests, we might roughly date the Somerville at 300,000 years ago, and the Harrisburg at between 600,000 and 750,000 years ago. This is purely a guess, based on relative deepening of the river channel.

The Harrisburg peneplane is thought to date from early glacial time, the Allegheny-Chambersburg peneplane from late Pliocene time, the Schooley from late Miocene time.

In a paper published since the foregoing was written, Campbell* again suggests that the Piedmont area of southeastern Pennsylvania has derived its present height, in part at least, as a result of elevation initiated in post-Chambersburg time affecting that plane and to a lesser degree the Harrisburg peneplane as shown in Figure 33A.

At its highest point in Maryland, the south slope of this arch is in close agreement with the hilltop surface shown in Figure 26 and cor-

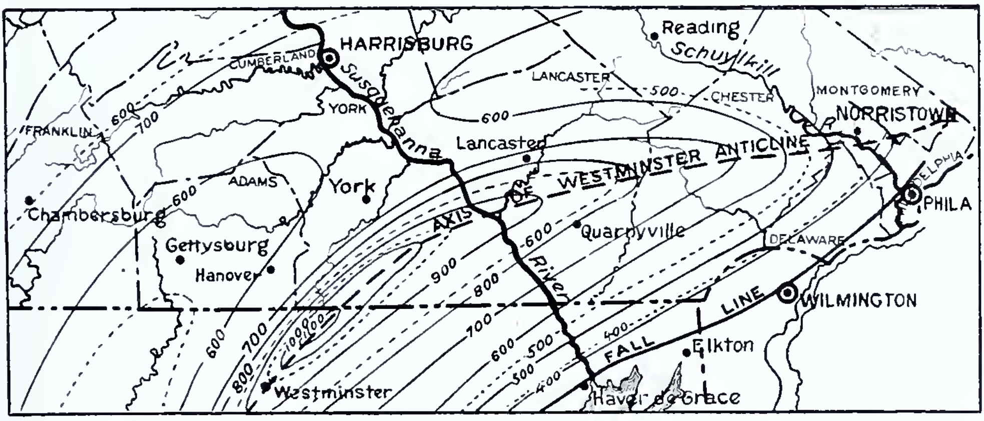


Figure 33-A. Map showing deformation of Chambersburg and Harrisburg (Bryn Mawr berm) peneplanes, as proposed by Campbell. Solid lines Chambersburg peneplane, dotted lines Harrisburg peneplane.

* Campbell, M. R., Chambersburg (Harrisburg) peneplane in the Piedmont of Maryland and Pennsylvania: Bull. Geol. Soc. of Am., vol. 44, pp. 553-573, June, 1933.

related as the trace of the deformed Schooley peneplane. The evidence for the supposed decline of the Westminster anticline toward Norristown is not made clear nor why the highest point should be placed south of the State line near Westminster, as similar high elevations are reached at the theoretic hilltop surface entirely across southeastern Pennsylvania and on into New Jersey where it coincides with the top of Schooley Mountain.

It may be granted that the Philadelphia-Trenton area was close to the hinge line between the uplifts that to the west have raised the Schooley peneplane to its present position and the sinking on the east that has sunk the sub-Cretaceous and Tertiary surfaces to their present position below sea level. The uplift and sinking in the belt mentioned has been less than it was farther west or east and the several erosion surfaces have been thought nearly to coincide in that area. It seems probable, however, that the hinge line has traveled southeastward with time, in Cretaceous time lying well within Pennsylvania, possibly near the center of the State and gradually shifting southeastward so that at the time of the last uplift it may have been well over in New Jersey. This is indicated by the fact that the present hilltop surface lies between 300 and 400 feet A. T. at Philadelphia and that the topography in the Philadelphia region suggests very recent uplift, possibly post-glacial.

HYPOTHETICAL PALEOZOIC SECTION
ACROSS THE GREAT VALLEY AT HARRISBURG

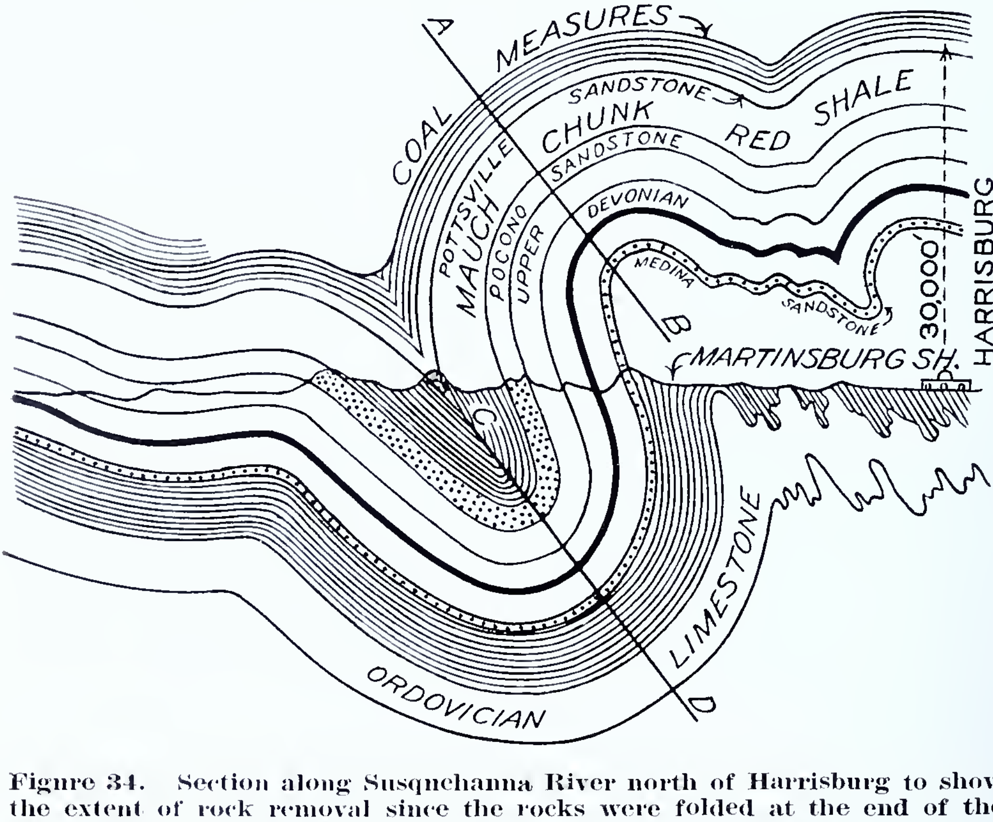


Figure 34. Section along Susquehanna River north of Harrisburg to show the extent of rock removal since the rocks were folded at the end of the Carboniferous. Vertical and horizontal scale, one inch equals approximately four miles.

On the other hand it is highly probable that these uplifts, were we able to restore the several surfaces involved, would show vastly more irregularities than is indicated in Figure 26 and 30. This subject is discussed more fully beyond under the title "Correlations across the Piedmont."

The Appalachian peneplanes have been the subject of study by many people during the last ten years. In addition to the brief outline and references given elsewhere, the reader may wish to follow the subject further. The following papers may be of interest:

Sharp, Henry S., The Fall Zone Peneplane: Science, May 24, 1929, vol. LXIX, no. 1795, pp. 544-545.

Shaw, E. W., High terraces and abandoned valleys in western Pennsylvania: Jour. of Geol., vol. XIX, no. 2, February-March, 1919.

Eaton, H. N., Some subordinate ridges of Pennsylvania: Jour. of Geol., vol. XXVII, no. 2, February-March, 1919.

Fridley, H. M., Identification of erosion surfaces in southcentral New York: Jour. of Geol., vol. XXXVII, no. 2, February-March, 1929.

Fridley, H. M., and Nölting, J. P., Jr., Peneplains of the Appalachian plateau: Jour. of Geol., vol. XXXIX, no. 8, November-December, 1931.

Ward, Freeman, The role of solution in peneplanation: Jour. of Geol., vol. XXXVIII, no. 3, April-May, 1930.

Ver Steeg, Karl, Wind gaps and water gaps of the northern Appalachians, their characteristics and significance: Ann. rept. of N. Y. Acad. of Sci., vol. XXXII, pp. 87-220, 1930.

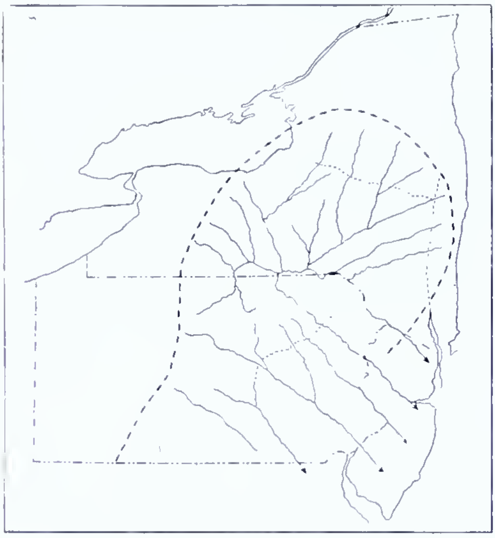
PREGLACIAL DRAINAGE IN PENNSYLVANIA

Early drainage. Drainage in Pennsylvania must have started as soon as the folding of the Appalachian revolution raised the tops of the anticlines above sea level. As folding progressed, the drainage would have been controlled by the troughs of the synclinal folds. If the rocks that have been removed by erosion were replaced in their folded position it is unquestioned that the southwest corner would be the lowest place in the State and so the drainage outlet, being in the center of the geosyncline of western Pennsylvania. A little later, during Triassic time, a trench was formed by the sinking of one or more fault blocks and, undoubtedly, the local drainage was into those sunken areas. Just where the water escaped is not clear now. What happened in southeastern Pennsylvania before the beginning of the Appalachian revolution is uncertain. There is some evidence that folding and uplift in that part of the State began long before the end of the Carboniferous and that at the time of post-Carboniferous folding, southeastern Pennsylvania had already been long uplifted and deeply eroded, this erosion having possibly furnished much of the material for the rocks of Carboniferous age and possibly those of still earlier ages. If that is true, the rocks of southeastern Pennsylvania may not have been folded and uplifted during the Appalachian revolution but served simply as a driving mass pushing against the rocks to the west; in that case, southeastern Pennsylvania would have remained low and drainage may have been toward that section of the

State. This, however, is still largely conjectural and has little bearing on the drainage as we know it today.

Beginnings of present drainage. The drainage of today conforms in the main to the southeastward and northwestward slope of the deformed Schooley peneplane, or of the later Allegheny peneplane, and to the trend of the rock folds. The Schooley plane has been completely destroyed west of Chestnut Ridge by erosion. The center of uplift of the Schooley peneplane runs from Somerset County to the eastern edge of Clearfield County, thence north through Potter County, and possibly northeastward to the Adirondacks, thence apparently southeast to the highlands east of the Hudson, possibly returning southwest into northern New Jersey (see A, Fig. 35).

Southeast drainage. Johnson* suggests that our present southeastward-flowing streams derived their original southeastward set as a result of differential uplift of Coastal Plain deposits of Cretaceous



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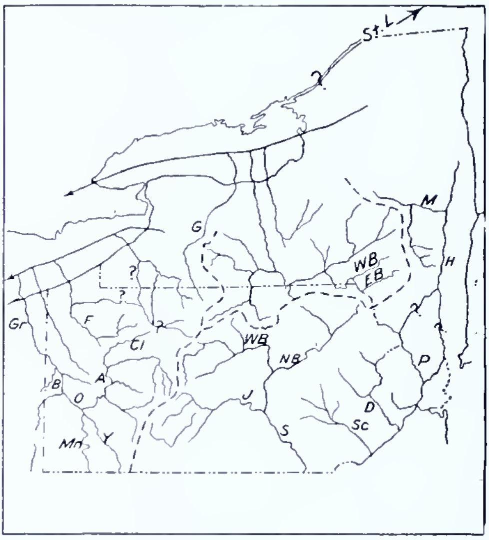

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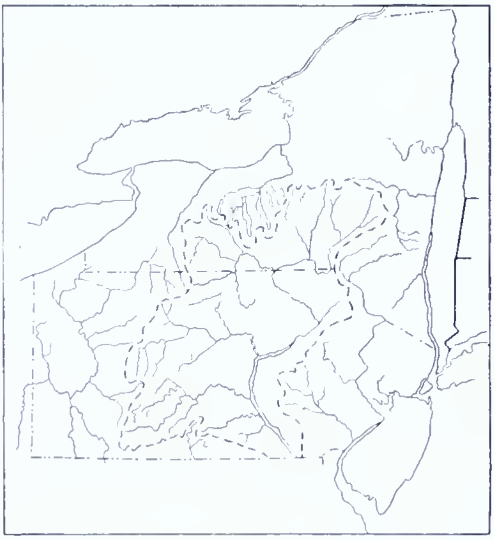

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Figure 35. Evolution of preglacial drainage.

A. Hypothetical early drainage of upper waters of Susquehanna based on slope of deformed peneplane; and lower drainage in eastern and central Pennsylvania based on uplifted blanket of marine deposits, not necessarily coincident in time.

B. Hypothetical preglacial drainage, the upper Susquehanna draining northward; and the lower southward much as today.

C. Present drainage.

* Johnson, Douglas W., Stream sculpture on the Atlantic Slope: Columbia University Press, 1931.

and later age following the submergence of pre-Cretaceous and later peneplanes. Uplift and subsequent erosion has since removed not only all of those deposits in Pennsylvania, but the planes on which they lay. See A, Fig. 35.

According to this theory, the lower Susquehanna and lower Juniata had about their present courses. The West Branch from Sunbury to Muncy may have been a tributary of the ancient Schuylkill of which the main head may have been in Cameron County and its course directly southeast. The North Branch above Pittston may have been the headwaters of the old Lehigh or of a parallel river somewhat farther east, of which little trace remains. See Figure 36. The Delaware above Port Jervis may have been the headwaters of a stream flowing southeastward past Franklin Furnace, N. J. Both Fairchild and Ruedemann have suggested that the upper Susquehanna and Chenango rivers of New York originally headed in the Adirondacks, and were subsequently beheaded by the Mohawk; also that the headwaters of the Delaware (above Hancock) were tributary to this upper Susquehanna from the east. Fairchild concluded that the combined rivers flowed southward across Susquehanna County and that the present Susquehanna below Towanda follows a branch that formerly headed at Towanda. Ruedemann* concludes that the East Branch of the Susquehanna and the East and West branches of the Delaware originally rose in the Highlands east of Hudson River, and flowed west over the crests of the Catskill Mountains in old valleys now occupied by the headwaters of the Schoharie, at a time when the tops of the Catskill Mountains were parts of an old plane sloping southwest and before the Schoharie had captured these tributaries. Here, as at the heads of the Unadilla and Susquehanna, the streams start in old valleys at the very crest of the escarpment, pointing toward the conclusion that the original sources were far beyond the present heads.

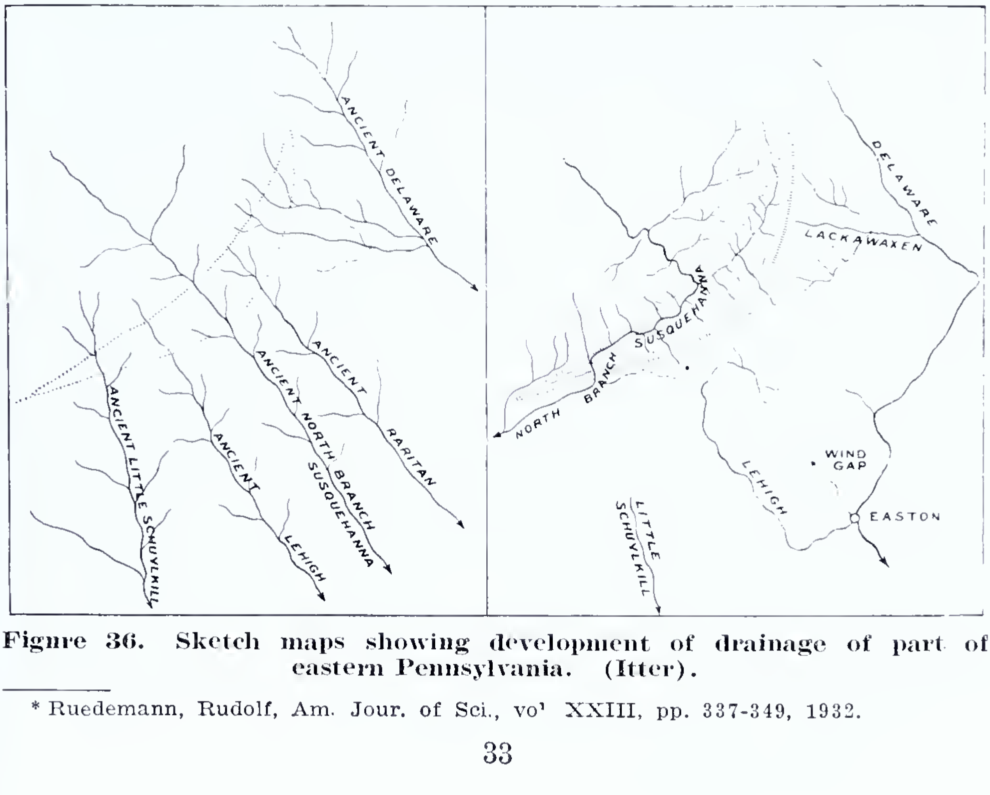

Figure 36. Sketch maps showing development of drainage of part of eastern Pennsylvania. (Itter).

* Ruedemann, Rudolf, Am. Jour. of Sci., vol XXIII, pp. 337-349, 1932.

Later adjustments. The subsequent history seems to have been largely that of adjustment to the underlying hard and soft rocks, the eastward extension of branches of the several rivers until they reached and beheaded the streams farther east, and the northward extension of south-flowing streams, such as the upper Delaware and Hudson, to behead certain of the southwestward-flowing tributaries of the upper Susquehanna, which now form the East and West branches of the Delaware.

Thus, a north-south tributary of the lower Susquehanna flowing over the soft rocks of its present course above Duncannon, extended its head to capture the former head of the old Schuylkill at Sunbury. Then a tributary pushed east in soft shales, forming the North Branch valley until, according to Itter, it tapped the headwaters of the Little

Figure 36-A. Wind gap northwest of Archbald, Lackawanna County. Formerly a water gap; abandoned when the stream flowing through it was diverted elsewhere.

Schuylkill which had started the gaps north and south of Shickshinny. An eastward tributary at Shickshinny then, or earlier, pushed on in the Mauch Chunk shales until it tapped the head of a tributary of the Lehigh responsible for starting the gap at Nanticoke. From Nanticoke a tributary pushed eastward through the Coal Measures of the Wyoming Valley to Pittston where the upper Susquehanna was captured and turned southwestward. In the same way, according to Itter, the primitive Lackawanna pushed northeastward and captured the former heads of the Lackawaxen and other streams running to the Delaware River.

At the same time, the southeastward drainage of central Pennsylvania was being broken up by streams creeping headward in the belts of soft rock running from northeast to southwest in conformity with the structure and rock folding; such were Bald Eagle Creek, Penns Creek, Middle Creek, and many tributaries of the Juniata running northeast and southwest. This adjustment of the drainage to the rock folds resulted in numerous wind gaps, abandoned by streams which had been diverted from their original southeast courses.

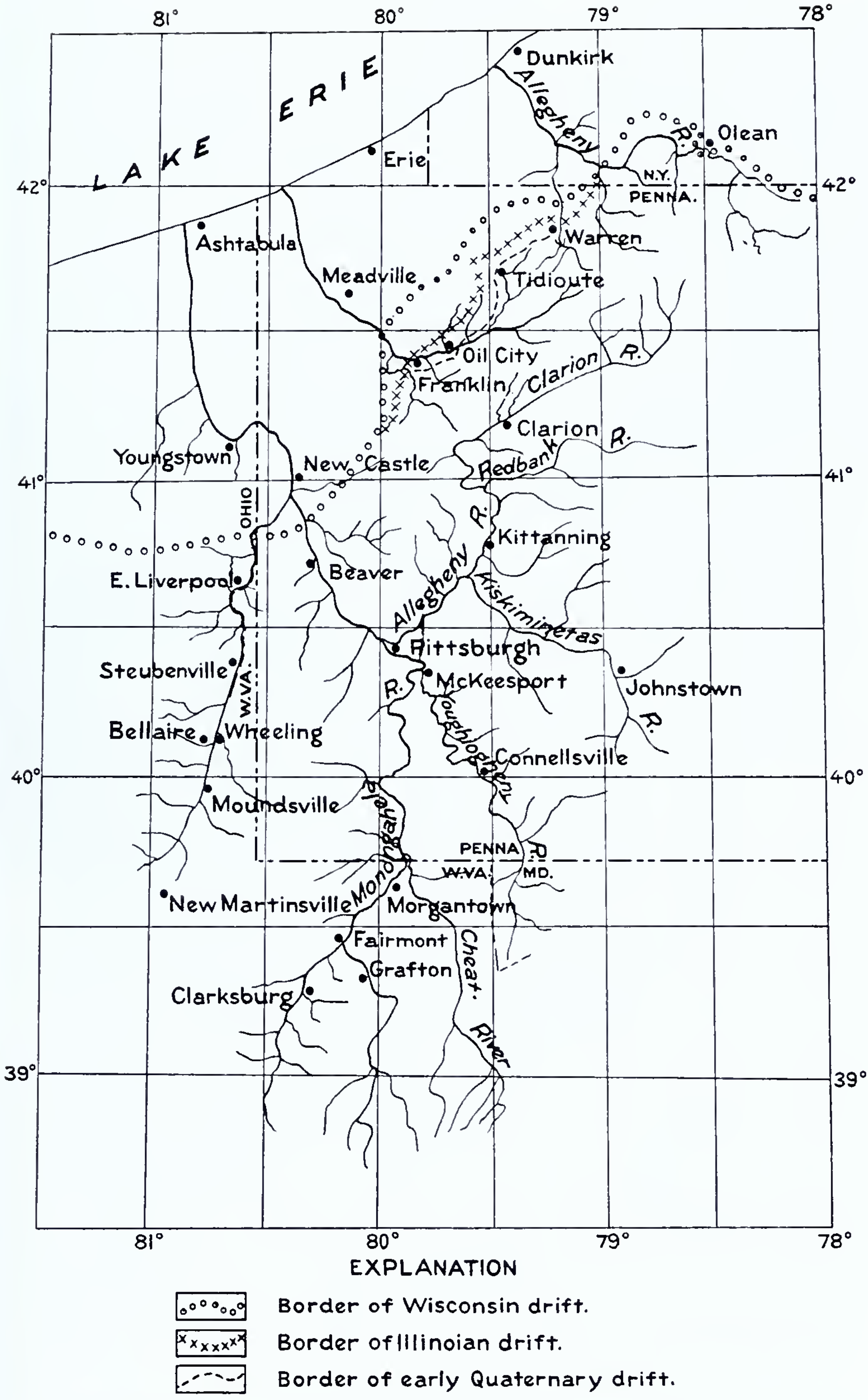

Figure 37. Preglacial drainage of western Pennsylvania, after Leverett.

Western Pennsylvania. The preglacial drainage of all of western Pennsylvania was northwestward to what is now the valley of Lake Erie; or down the slope of the deformed Allegheny peneplane to the line of the Ohio-Beaver drainage, as shown in Figure 37.

Much work needs yet to be done on this problem, especially on the drainage of the upper waters of French Creek. As shown in Figure 35, the headwaters of many of the streams formerly draining westward were later captured by the West Branch of the Susquehanna. This includes the present heads of Anderson Creek, of Clearfield Creek, and the other tributaries of the West Branch west of Clearfield Creek. Probably this capture was in preglacial time. At present, Beaver Dam branch of Clearfield Creek is threatening to undercut and divert Chest Creek at Patton. The drainage shown in Figure 35 should be compared with the map of the present system.

The Upper Susquehanna. The headwaters of the Susquehanna present some interesting problems. The present fan-shaped drainage suggests that the Susquehanna in New York was in a basin formed by the unequal uplift of either the Schooley or the Allegheny peneplane. At the time of the uplift the Pocono sandstone may have been intact. If so its base if replaced today would be 6,000 feet A. T. in the Lake Ontario area, and still higher in the Adirondack and Catskill areas, as contrasted with between 2,000 and 3,000 feet in Tioga, Bradford, and Susquehanna counties in Pennsylvania.

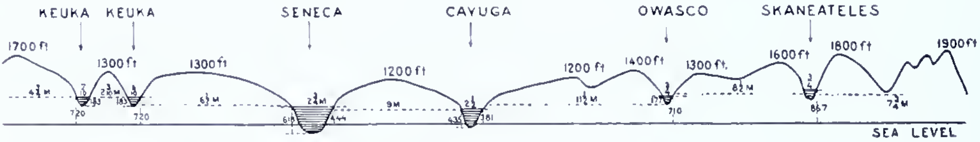

Figure 38. Hilltops in the Finger Lake region suggest either an old erosion basin, or a deformation "low" of an old peneplane centering in the Seneca-Cayuga lake region, New York.

As show in Figure 38, the present hilltop topography across the Finger Lake region in New York suggests either an old erosion basin or a deformed peneplane with a low axis lying about parallel to Seneca and Cayuga lakes, similar to that followed by the branch of the Susquehanna between Cooperstown and Binghamton, N. Y. It suggests that a principal head of the old river may have flowed southeast parallel to Seneca Lake from some point far to the northwest. In either event, erosion on the north probably moved the divide farther southward in this low area than where the land was higher either side. Probably in preglacial time the divide had been carried as far south as Watkins and Ithaca. It may have gone even farther and have reached into the Elmira region from the line of Seneca Lake or to Owego and Binghamton from the line of Cayuga Lake, and thus have diverted the present west and east heads of the river toward the drainage in the Lake Ontario area. So much change has occurred in southern New York during glacial time that it is not yet clear whether such a diversion, which would seem certainly to have taken place, occurred before the Ice age, or not. Ice, moving back and forth in the Seneca and Cayuga basins, dug those basins far below sea level, as shown in figure 37, and thus after the retreat of the ice

produced a high gradient from the south that would have given a great advantage to the northward drainage and so might have diverted all of the headwaters of the Susquehanna northward in middle or late Ice age time. To settle this problem much more data on the depth of valley fillings and the elevation of the rock floors of the valleys of that part of New York State must be obtained.

THE ICE AGE

General. The Ice age, which is thought to have covered the last million years or so of geologic history, began when changing climatic or other conditions, caused the accumulation of great bodies of ice that ultimately became several thousand feet thick in the Labrador region, west of Hudson Bay, in the northern Baltic Sea, and elsewhere in the northern part of the globe. As this ice accumulated it began to flow away, as asphalt may flow on a flat surface on a hot day. Ultimately, this ice pushed its way southward into the northeastern and northwestern corners of Pennsylvania. It is now generally recognized that changing climatic conditions caused the ice to advance and retreat four times. Three of these advances are thought to have left recognizable records in both northeastern and northwestern Pennsylvania. These four clearly distinguishable advances in the Mississippi Valley have been called the Nebraskan, Kansan, Illinoian, and Wisconsin ice sheets. The last of these in the eastern part of the United States has sometimes been called the Labrador ice sheet. One of the earlier incursions in New Jersey has been called the Jerseyan ice sheet.

Figure 39. Sketch showing centers of ice distribution in eastern North America.

The advance of these masses of ice is believed to have been very slow and intermittent, possibly with many minor retreats and much back and forth movement in the same way that mountain glaciers today move back and forth. Rise in temperature resulted in a gradual decrease in the amount of ice and a retreat of the ice front.

Figure 40. Rock surface, scratched and polished by overriding glacier. Photo by R. W. Stone.

Geologic action. The ice acted as a geologic agent by scraping up all of the loose rock in its path and pushing or carrying it forward. Hard rocks frozen into the bottom of the ice acted as scraping tools, cutting and polishing rocks over which the ice passed and were themselves worn flat and smooth on the sides adjoining the underlying rock, or faceted, as it is called. Where the ice moved over softer rocks such as shales, it obviously dug deep into the solid rock and

Figure 41. Boulders on shore of Lake Erie. The larger boulder is Onondaga limestone, of which the nearest outcrop is 40 miles north in Canada. The smaller boulder in the foreground is gneiss, from several hundred miles away.

locally gouged out deep valleys, such as those of the Finger Lakes or Great Lakes. As the ice advanced over irregular hills and valleys much of this scraped-up material was deposited in the valleys, particularly those running traverse to the direction of movement of the ice. Some of the glacial burden was carried forward for long distances, even hundreds of miles, as is indicated by the fact that in the glacial deposits of northern Pennsylvania boulders of granite and gneiss occur as well as other rocks that do not outcrop within many miles of where the boulders are found.

The ice probably overtopped the Catskill Mountains of eastern New York and was thick enough to override all of the mountains in its course in Pennsylvania. Its front would naturally be somewhat affected by the topography, steep-sloped tongues pushing down the valleys that lay parallel to its direction of motion and giving the ice front a toothed appearance. Likewise the direction of motion was controlled more or less by the earth's surface.

Figure 42. Glacial till, top of Pocono Mountain plateau near Tobyhanna, 2,000 feet above sea level.

Glacial deposits. The deposits left by the retreating ice sheet are described under several names. A blanket of "till" left over nearly the whole area was 10 to 25 or more feet thick and consisted of an indiscriminate mixture of clay, sand, and boulders of all sizes, some worn flat and possibly scratched on one side, just as they were dropped by the ice. It is also distinguished by not grading down into the underlying rock, as soil formed in place does, and by the presence of foreign rocks, or rocks brought from outside the drainage basin. Some of the "clay" may prove on examination to be rock flour, ground sandstone or limestone. Where the front of the glacier stood a long time, because melting just compensated for the forward movement, there usually accumulated an irregular deposit known as terminal moraine that might form hills several hundred feet high. Similar moraines may have been left at many points where the retreating glacier paused

Figure 43. Esker northeast of Susquehanna village.
Figure 44. Morainic hill northwest of Susquehanna village.
Figure 45. Big kettle northwest of Berwick, Luzerne County.
Photos by H. L. Fairchild.

long enough. Streams flowing under the glacier deposited sand and gravel in ice-walled channels. The melting ice left these deposits as long ridges characterized commonly by a level top and steep sides, the top often being wide enough for a road or footpath. Such ridges, called eskers or kames, are found in the northeast part of the State in particular. Where the ice stood still and melted in place there resulted an irregular accumulation somewhat like dirt dumped in a vacant lot and partially smoothed out. Such irregular deposits are likely to be found along the edge of valleys where stagnant ice lay for some time in the center of the valley while water, accumulated between the ice and the bank, would deposit its load of debris. If waters were ponded between the ice and bank, entering streams might form delta terraces at various levels (if the ponded waters varied in level). (See under Wyoming Valley).

Figure 46. Valley of Pine Creek, a post-glacial gorge cut through the preglacial divide south of Ansonia. Photo from Harrison Park by Bradford Willard.

A moraine is likely to show many undrained basins or "kettles" from a few yards wide and a few feet deep to scores of feet wide and many feet deep. The kettles were formed by the melting of a great block of ice left buried in the moraine or outwash gravel.

Drainage changes, lakes, etc. Glacial deposits are likely to make many changes in the drainage of the affected region. Thus, in places, as the ice moved forward up a drainage basin, the streams flowing toward the ice were ponded against its front until the pond rose to such a height that it overflowed the edge of the basin into some other valley draining away from the front of the ice. This may have lasted long enough so that a new, permanent outlet was established by cutting a deep gorge through the old rim of the basin. This happened, for example, with Pine Creek the headwaters of which were tributary

of the Tioga River by way of Marsh Run. The gorge below Ansonia was cut through the rim of its old basin, making Pine Creek a tributary of the West Branch of the Susquehanna. This process shows on a smaller scale, though more plainly, on Sugar Creek in Bradford County as in Figure 47.

Glacial deposits may have filled a valley so completely that the stream formerly occupying it failed to find its old channel and escaped from its old valley over some low spot in the rim. Where the stream reached a valley not filled with glacial débris, it poured over the edge in a waterfall. In time such a waterfall would wear its channel back from the open valley several miles, making a deep, narrow gorge. This is particularly true in Pike County where the ice moving through and parallel to the Delaware Valley kept that valley open, but filled up the tributary valleys from the north so completely that most of their streams found outlet over the old rock rim and today form waterfalls that are a most pleasing feature of the area.

Figure 47. Sugar Creek has broad, flat bottoms except at one point where it flows through a rocky gateway as shown. The upper waters formerly were the head of South Creek; but ice ponded and diverted them over this divide to Sugar Creek. In time they cut this gateway down to the level of the valley either side.

Irregularities in the blanket of glacial till, and the many streams dammed up by moraines, resulted in a great number of lakes of all sizes, many of them perched on top or on the flanks of the hills. In time these lakes fill up with sediments from the near by hills, are converted into swamps, and ultimately into flat land for pasture or cultivation.

In the western part of the State the drainage which originally had been northwest was ponded by the advancing ice so that the several basins contained temporary lakes. These rose high enough to flow over from one basin to the next, cutting notches in the divides and initiating what is today the Allegheny River. Likewise the old outlet of the Ohio up the Beaver Valley (200 feet above the present river)

was closed and its waters turned into a new course to form the present Ohio. In these instances the deflection of the water was a result of one of the earlier ice invasions, so much earlier that between the initial deflection and the time of the Wisconsin ice invasion the rivers at Pittsburgh deepened their channels 200 feet or more.

Areas covered by the ice. In the Mississippi Valley the terminal moraines of the earlier and later ice sheets are separated, at least in some regions, by considerable distances. In Pennsylvania the limits of the several advances of the ice are not so far apart. The Illinoian

Figure 48. Waterfall formed by a stream diverted from its former valley by glacial material and finding a new way over the old rock rim. Bushkill Falls. Photo by Pennsylvania Department of Highways.

ice, however, outreached the Wisconsin ice in eastern Pennsylvania an average of 50 miles and much less in western Pennsylvania. The earliest advance in Pennsylvania is represented only locally by existing deposits, and generally only by scattered boulders on the mountains, well above the reach of the later advances. The accompanying map by Leverett, Plate I, shows the position of the recognized farthest extent of the several advances. The main moraine was first mapped by H. Carvel Lewis and Frederick G. Wright in 1880-81. At that

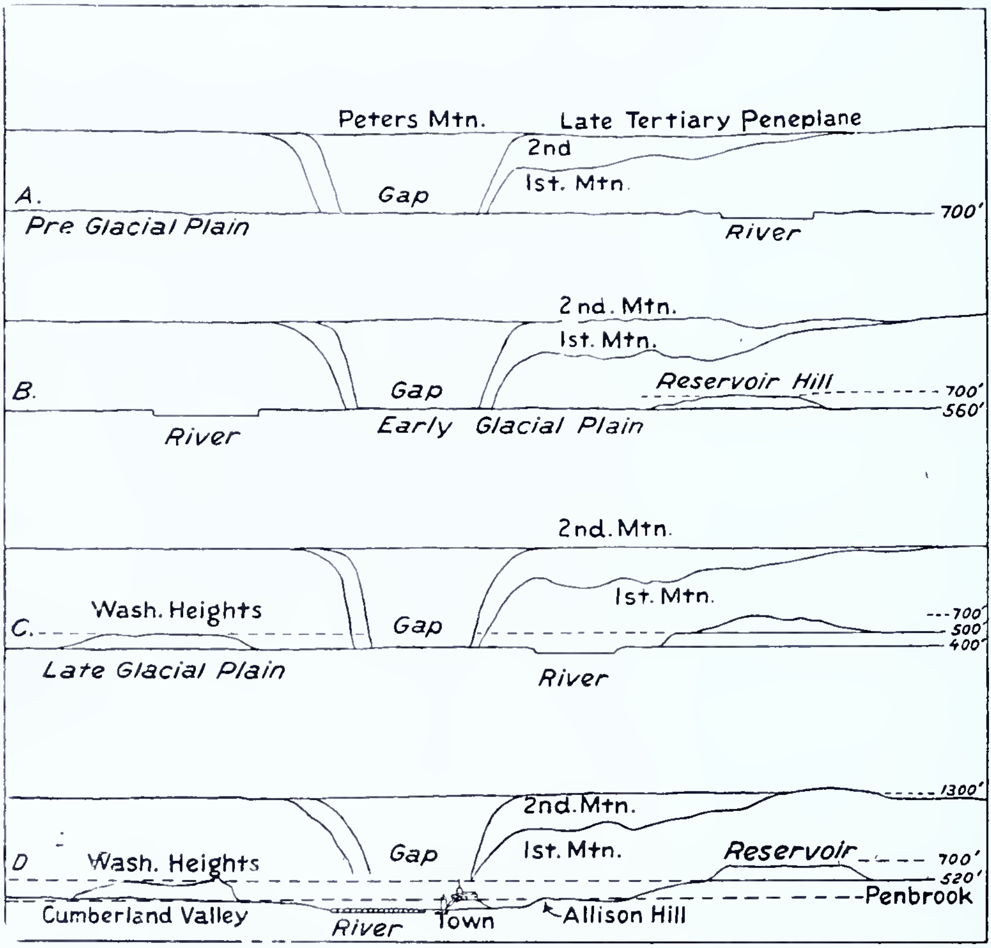

Figure 49. Chart showing stages in the downcutting of the Susquehanna at Harrisburg.

time the evidence of glaciation outside of the main terminal moraine was considered to be the result of a preliminary advance followed by a rapid retreat and a long standstill in the position of the main terminal moraine. Mr. Leverett has made many local changes from former mapping, especially in showing tongues in the deeper valleys that escaped the notice of the earlier workers. The mapping of the deposits outside the main terminal moraine is almost entirely the work of Mr. Leverett. Though much work had been done on these extra-terminal moraine deposits by E. H. Williams and others, the earlier geologists of Pennsylvania failed to recognize the evidences of greater age in these deposits, though long recognized in New Jersey.

Time elapsed and character of deposits of several advances. The evidence of time elapsed between earlier and later advances is twofold, intervening erosion, and the character of the deposits. As pointed out by Leverett, the older deposits may be distinguished by the greater extent of their weathering; shown first, by the leaching out of limestone in the older deposits within the reach of surface waters, the depth of leaching depending upon the permeability of the deposit being examined. Second, in the older deposits the cherts have changed to a white chalk-like substance that in some instances can be crushed in the hand. Third, more resistant pebbles may show pitted or bronzed surfaces. Fourth, granite or other crystalline rocks may be friable, due to the decay of the feldspar or may even be so decayed that they will crush in the hand or may be cut in two with a spade. Fifth, the older deposits are commonly a deep red, resulting from the oxidation of the iron in the deposit. Sixth, the older deposits are commonly more indurated. The younger deposits may be easily penetrated by a pick, while the older deposits may resist such penetration. These tests applied to the river bench gravels at several levels, as along the Delaware, Susquehanna, or Allegheny, show, if not at once, at least on close and patient study that these gravels are not remnants of a single deep filling, as has been thought by some of the earlier geologists, who considered the several gravel benches as representing stages in the clearing out of the river valley through a single gravel filling. Here as elsewhere, the evidence is not always clear and can be truly read only when all the evidence from many angles is assembled.

Valley erosion on Susquehanna. The downcutting of the Ohio at Pittsburgh has been referred to elsewhere. Similar studies in the Susquehanna show similar degrees of erosion, as indicated in Fig. 49. At (a) the river is at the Allegheny or Chambersburg peneplane level now raised to about 700 feet A. T. The river is supposed to have been sluggish and meandering (Late Tertiary time). At (b) the river is shown at the Harrisburg peneplane level, since raised to 560 feet A. T. (Early Glacial ?). Here, too, the land is supposed to have stood still so long that the rocks over a large area were reduced to this new level, especially over the soft and soluble rocks of the Appalachian Valley. Scattered boulders and cobbles found on the hills at this level all up and down the Susquehanna are thought to represent remnants of old river gravels of that age. In (c) there has been further uplift and downcutting resulting in slight peneplanation, known as the Somerville peneplane, and thought to date from not long before the time of the Illinoian ice advance. In (d) we have the present river valley. The Illinoian benches are covered with gravel-bearing evidence of greater age than the gravels under the center of the city, though this is not nearly so clear as further up the river, as in the Selinsgrove area.

Post-glacial streams. The time since the retreat of the last ice, as well as the time between the several advances, is also recorded in the depth and length of post-glacial or interglacial streams all over the glaciated region. The erosion that took place on the Allegheny-Ohio since its diversion and the subsequent partial filling by deposits of the Wisconsin ice age have been referred to. In Pike County, the length of the gorges below the waterfalls is a measure of the time

since the stream originally reached the valley by way of its open flank. Likewise the depth and width of the many gorges cut through old divides are a measure of elapsed time. A similar type of post-glacial stream is seen in the lower part of Slippery Rock Run in western Pennsylvania. The upper waters of Slippery Rock originally flowed west and entered the Beaver near New Castle. The ice, however, closed that outlet and turned the stream down what is now the lower part of Slippery Rock Valley. This valley is a narrow, deep gorge whose side tributaries have not yet been deepened to the bed of the main stream, but enter by a series of cascades or waterfalls. Tributaries normally, of course, enter the main stream at grade. One of the evidences that the North Fork of the Susquehanna may have headed at Towanda in preglacial time is found in the streams which reach the open valley some distance above the present river level, as is well seen, for example, at Rummerfield. The same thing is seen at New Milford, where the drainage formerly going northward has now been turned southward as a result of glacial action and a moraine at New Milford, as illustrated in Fig. 50 from a survey and photos by Hanford G. Russell.

Figure 50. A. View from station B (see sketch map D) looking east across present divide toward New Milford, just around the flank of the dark hill on the left. The present divide, now a swamp, obviously crosses an old valley in which the stream flowed east from tributaries entering from the right or south. B. View from station B, looking south, up the slope toward the old divide. Martins Creek, heading mainly from the right through a ravine behind the timber in the middle distance has cut the V-shaped, relatively narrow valley shown in the picture. C. View from station A, looking north toward station B, down the old headwater slope. The new valley, cut since the diversion, is at the left. D. Sketch map. (Russell).

These deep rock cuts are clear evidence of the time involved since the last advance of the ice or since one of the earlier advances, as it is not clear in each case just when the diversion took place. In some instances, the diversion may, indeed, have started with one of the earlier advances and the stream reoccupied the old valley until, during a later advance, the new outlet through the old divide was so deepened that the stream was permanently deflected to its present course.

Glacial deposits outside the moraines. Glacial deposits within the glacial area have been described. However, other typical deposits are found outside the glacial boundary. First are the outwash gravels which lie just outside the terminal moraine, whether this be the farthest or some intermediate moraine laid down during the retreat of the ice front. A most characteristic gravel of this type is seen at Berwick, which is built on this outwash plain. Pits near town indicate a thickness of this gravel deposit of 100 feet or more. On the south side of the river opposite Berwick are stages in the downcutting of this gravel deposit. Nescopeck lies on one of these plains of partial reduction and there are several others in this region. The plain, which is 100 feet or more above the river at Berwick, declines rapidly downstream until, as it has been traced by Leverett, it is only 40 feet above the river. Farther down, this becomes what is known as a valley train, following the river and expressing the depth of river cutting since the time of the Wisconsin ice lobe. Glacial deposits farther down the river, therefore, represent an extension of this plain or they represent reworked gravels at lower levels, as river benches covered with gravels are found at levels all the way from 40 feet down to the present flood plain.

RESULTS OF RECENT GLACIAL AND POST-GLACIAL STUDIES

DELAWARE RIVER DRAINAGE

Glaciation south of Delaware Water Gap. (Ward).

Recent studies have developed some local details that are of interest. Prof. Freeman Ward, as a result of studies in 1930-31, offers a new interpretation in the movement of the Wisconsin glacier south of Delaware Water Gap. It has previously been assumed that the Wisconsin ice overran Kittatinny Mountain at the Delaware Water Gap. He points out, however, that the ice that went over the mountain must have been of Illinoian age or earlier, and that Wisconsin ice in that region was flowing along the foot of the mountain and parallel to it from east to west, probably having overflowed the top of the mountain some miles east of the water gap. In support of this position, he finds that the glacial scratches on top of the mountain indicate that the ice that went over the mountain followed a nearly north-south direction; that those scratches, notwithstanding that they are in the Shawangunk quartzite, are very deeply weathered and obscure, whereas the east-west scratches in the valley to the south are still sharp and clear, notwithstanding that they were made on either limestone or sandy shales. He points out further that all the erratics found on

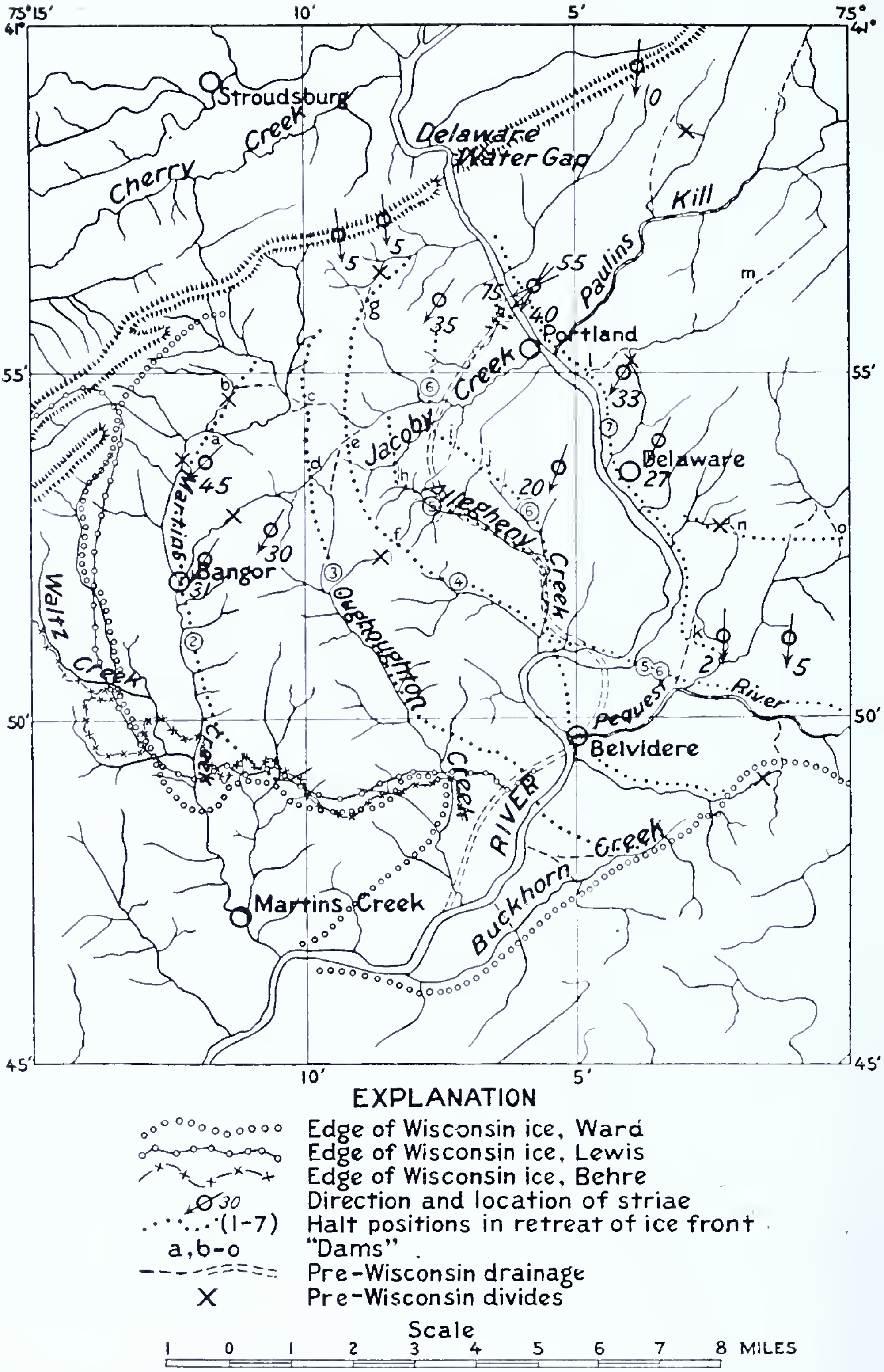

Figure 51. Wisconsin drift south of Delaware Water Gap; (Ward).

the mountain show a rind of weathering, even those of the Shawangunk quartzite; whereas the Shawangunk erratics in the valley do not show such a rind. Limestone is absent from deposits on the mountain but present in the valley deposits. He further points out that the terminal moraine west of Bangor lies north and south, running toward the mountain, but turns northeastward at the foot of the mountain and runs along it for several miles. Furthermore, he notes the absence of very large Shawangunk erratics south of the mountain, which would hardly be true if the material in the valley had been plucked from the adjoining mountain top.

Ward calls attention to till about 10 feet or more thick under stratified drift at Carpenterville, some 12 miles south of the Wisconsin terminal moraine. This drift has, he thinks, the earmarks of Wisconsin age and suggests that a narrow tongue of Wisconsin ice extended down the Delaware Valley to Carpenterville. His paper describes valley train terraces from Hutchinson to Riegelsville where the principal terrace is from 60 to 75 feet above the river, and secondary terraces at 30 to 35 feet and lower. In the Belvidere district the deposits on the river banks are irregular in form and elevation and suggest materials built around irregular masses of stagnant ice. These vary from 300 to 440 feet A. T. A main terrace 40 feet above the river at Delaware bridge descends to 30 feet at Hartzels Ferry, and to 25 feet above the river still farther down the valley.

Illinoian drift in eastern Pennsylvania. (Leverett).

South of Kittatinny Mountain. The Illinoian drift covered all of the Lehigh Valley between Kittatinny and South mountains from the Delaware River to a line a few miles west of Lehigh River above Allentown. It occurs near Riegelsville and spreads through the gap east of Bethlehem into Saucon Valley, as shown in Fig. 52. The ice produced a distinct moraine on the limestone lowland west of Allentown and there are morainic features in the Saucon Valley. This moraine had a relief of 20 to 40 feet and in places a width of half a mile to one mile. Within this area the topography is mostly of the swell and sag type much subdued. Except in the morainic areas, the drift is very thin, hardly forming a complete cover. Depressions may have been filled to depths of 30 feet, as shown at many of the slate quarries. At Bethlehem (west end) a well penetrated 137 feet of unconsolidated material, or to 40 feet below river level.

The Illinoian drift consists of reddish clay till with locally enough sand and gravel for commercial use. The boulders in it are mostly of local origin though some came from the north. Some gneiss from South Mountain is included. Limestone has been leached from the deposits to a depth of 15 feet or more. Pits show the till resting on river gravels of earlier age. Leverett discusses the probable existence of Lake Packard as described by Williams, but interprets the evidence differently.

North of Kittatinny Mountain. In this region the boundary is not clearly marked, but tongues of ice projected up the western tributaries of the Lehigh, causing ponding and discharge into the Schuylkill. Fluvial glacial material along these lines of discharge obscures the

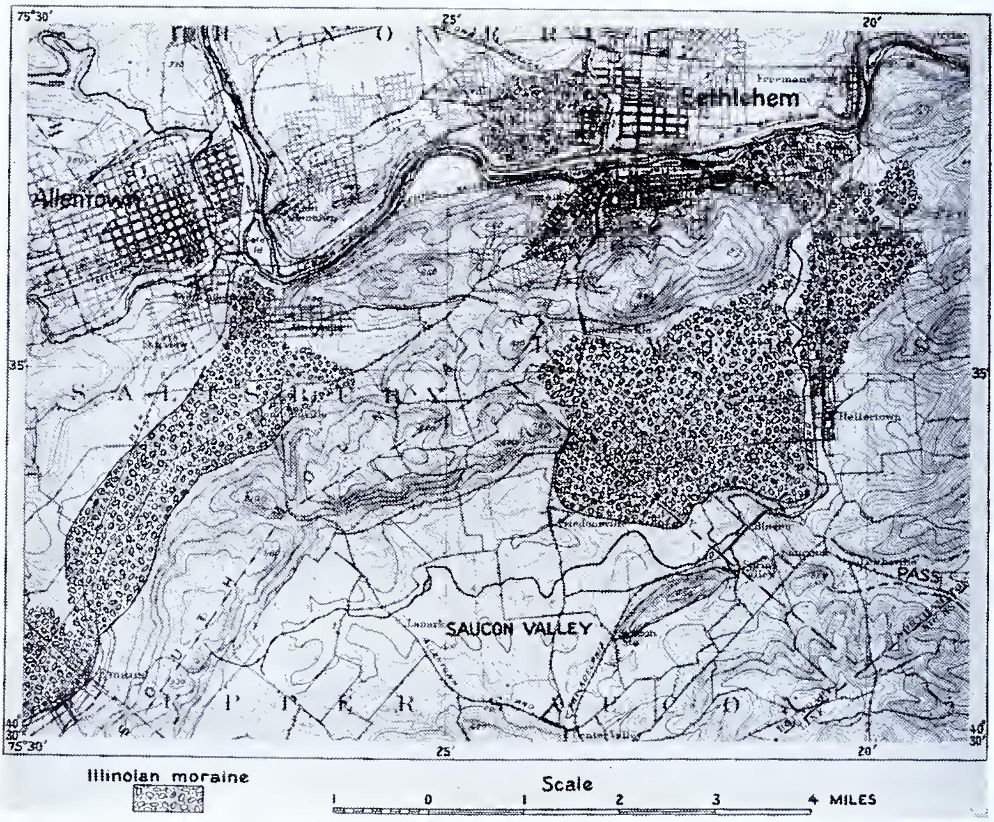

Figure 52. Illinoian marginal drift in Allentown-Bethlehem region. (Leverett)

boundary. Ice appears to have covered Pocono and Pohopoco mountains west to the Lehigh River near Palmerton and south to Pohopoco Creek. The boundary is obscure in the north part of the Hazleton and south part of the Wilkes-Barre quadrangles because of the presence of pre-Illinoian till. Near Zehner the Illinoian is so thick that Lewis included it with the Wisconsin; but it is more deeply weathered.

The material is generally from 0 to 30 feet thick but locally up to 150 feet (178 feet in Lehighton). It is noncontinuous, reddish, clayey till with local rocks predominating. Leverett's manuscript gives detailed evidence of its distribution. With the lower Lehigh covered with ice, escape for the glacial waters should naturally have been westward to the Little Schuylkill, though none of the passes give clear evidence of such outlets.

Pre-Illinoian or Jerseyan drift. (Leverett).

Evidence is obscure as to the presence or extent of this drift south of Kittatinny Mountain. It was thought by Williams that Jerseyan ice followed the Appalachian Valley to Reading. This is doubted, but not denied, by Leverett, who thinks that supposed morainic material on the north side of South Mountain is talus and not drift. Judging by the distribution of this drift in New Jersey, it seems likely to have outreached the Illinoian glaciation, though that is not certain.

North of Kittatinny Mountain, this drift occurs in the headwaters of the Little Schuylkill, on the divide between the Lehigh and Susque-

hanna rivers, between Nesquehoning and Pisgah mountains, and near Lansford, Coaldale, and Tamaqua. Deposits are patchy, 5 to 15 feet thick, and occupy less than 10 per cent of the surface. Near the head of Silver Brook, there is 80 feet of till. This till is loose textured, rather stony, and many of the stones are well rounded and up to several feet in diameter. On the uplands the drift is clayey, thickly set with small stones, mainly of local origin, though locally with such a wide variety of rock as to involve considerable transportation. Many of the stones are striated. Over much of the Eastern Middle Anthracite field there is a nearly continuous stony clay 8 to 12 feet thick, as exposed around mine workings. It is not entirely clear whether this may not be residual clay.

Outwash gravels from the pre-Illinoian are abundant. Terraces with fluvial material occur in places at 40 to 50 feet or even 80 feet above the present drainage, especially between Kittatinny and South mountains on the Schuylkill. It is not clear that these connect with the drift. Near Reading 20 feet of clay alluvium with boulders and cobbles is exposed along the Belt Line Railroad 70 feet above the river, and 60 feet above the river north of Milmont on the Pennsylvania Railroad. This terrace seems, according to Leverett, to tie into the Brandywine plain which Campbell* traced down the Schuylkill at about 200 to 225 feet A. T. at Pottstown. From there the terrace is level, at least to Norristown. A lower terrace at 140 feet A. T., which may be of glacial age, was traced by Campbell from Pottstown to Norristown. At Reading, fluvial deposits occur on a well-defined terrace 80 to 100 feet above the river (280 to 300 feet A. T.), which Campbell correlates with the Bryn Mawr formation, that is shown in the Philadelphia folio on a surface rising northward to 460 feet A. T.** I correlate the Bryn Mawr gravels of the Philadelphia region with any boulders that may be found on the hilltops at 520 feet A. T. in the northwest part of the Reading quadrangle (Harrisburg peneplane). Much more study of the terraces and gravels of southeastern Pennsylvania is needed before definite statements can be made. Leverett gives the elevation of the terrace above Pottstown as follows:

ALTITUDE OF RIVER AND TERRACE ABOVE SEA LEVEL.

	River	*Terrace*		*River*	*Terrace*
Shoemakersville ...	300	380	Milmont Junction .	185	265
Mohrsville	280	365	Gackenville	150	250
Tuckerton	250	340	Douglassville	130	230
Glenside	200	280	Pottstown	120	220

Terrace gravels in the Delaware Valley are not easily distinguished from the material left by the decay of the Triassic conglomerates, so that it has not been possible to distinguish outwash gravels of glacial age. Pensauken gravels according to Leverett occur at Trenton 120 feet A. T., and at the following elevations upriver: Titusville 140 feet, New Hope 140 to 160 feet, Raven Rock 200 feet, or 130 feet above the river. Campbell (personal communication) has recently pointed out that the main drainage in Pensauken time was apparently

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* Campbell, M. R., Late geologic deformation of the Appalachian Piedmont as determined by river gravels: Nat. Acad. of Sci., vol. 15, no. 2, pp. 156-161, Feb. 15, 1929.

** Bascom, F., and others, Geologic atlas of the United States, Philadelphia folio, no. 162, p. 12 and geologic maps.

not down the present Delaware above Trenton, but reached Trenton by way of Millstone Creek and Raritan River. Some of the material passed Franklin Furnace, as this deposit in the lower Delaware contains chert which can be traced back over the course just mentioned to northern New Jersey. This chert increases in quantity as the outcrop is approached. It may prove that this deposit was laid down while ice covered the middle Delaware, though that is purely conjectural.

In particular, Campbell believes that the Pensauken formation in the Delaware Valley was not laid down in a basin carved out of the Bridgeton formation that in New Jersey occurs at a somewhat higher level, but that the Bridgeton is the Pensauken formation raised to a higher level away from the Delaware by crustal deformation. Leverett has noted the marked similarity of the two formations in their rock content, weathering, etc. He concludes from its erosion and weathering that the Pensauken may be of the age of the Jerseyan drift. Similar deposits at Broomall, Pennsylvania, 360 to 380 feet A. T. are thought by Dr. F. Bascom to be of later age than the Bryn Mawr and referable to the Brandywine formation. The whole subject of the correlation of these gravels and terraces with the later peneplanes awaits more detailed studies, but gives promise of a satisfactory solution.

SUSQUEHANNA DRAINAGE

Within Wisconsin Border

Wyoming buried valley. (Darton, Fairchild, Itter, et al.) The Wyoming buried valley was studied by N. H. Darton* in 1913, by H. L. Fairchild in 1921-23, and by H. A. Itter in 1931. These men have thrown considerable light on the history of this valley.

Figure 53 taken from Darton's report shows the configuration of the buried valley by contours and in "B" the thickness of deposits. It is to be noted first that the rock bottom of this valley has been cut down in places to less than 250 feet above sea level, while just above Berwick rock crosses the river at 480 feet A. T. and at no place farther down stream does the rock reach so low a level until in the neighborhood of Middletown. A study of the large depressions in the rock floor taken in connection with the fact just stated makes it difficult to ascribe this buried channel to river action. The lower points in the channel bed are of quite distinct character from the so-called "deeps" of the lower river to be mentioned further on. On the other hand the rock bottom of the basin does not have the smooth and level character of ice-cut basins. It has, therefore, been agreed that the basin probably represents a combination of glacial scouring and erosion by water under the ice. The fact that the deep channels extend nearly 20 miles along the North Branch from above West Pittston apparently to below West Nanticoke strengthens the idea of water having a share in the erosion of this channel. Fairchild quotes H. S. Spaar as stating that drilling for the Shickshinny bridge failed to find rock at 44 feet below river level (447 A. T.). Itter expresses the belief that the hidden channel was cut mainly by ice, but modified by subglacial erosion. At the Empire Colliery at Wilkes-Barre, accord-

*Darton, N. H., Wyoming Historical and Geological Society, Proc., pp. 41-64, 1914.

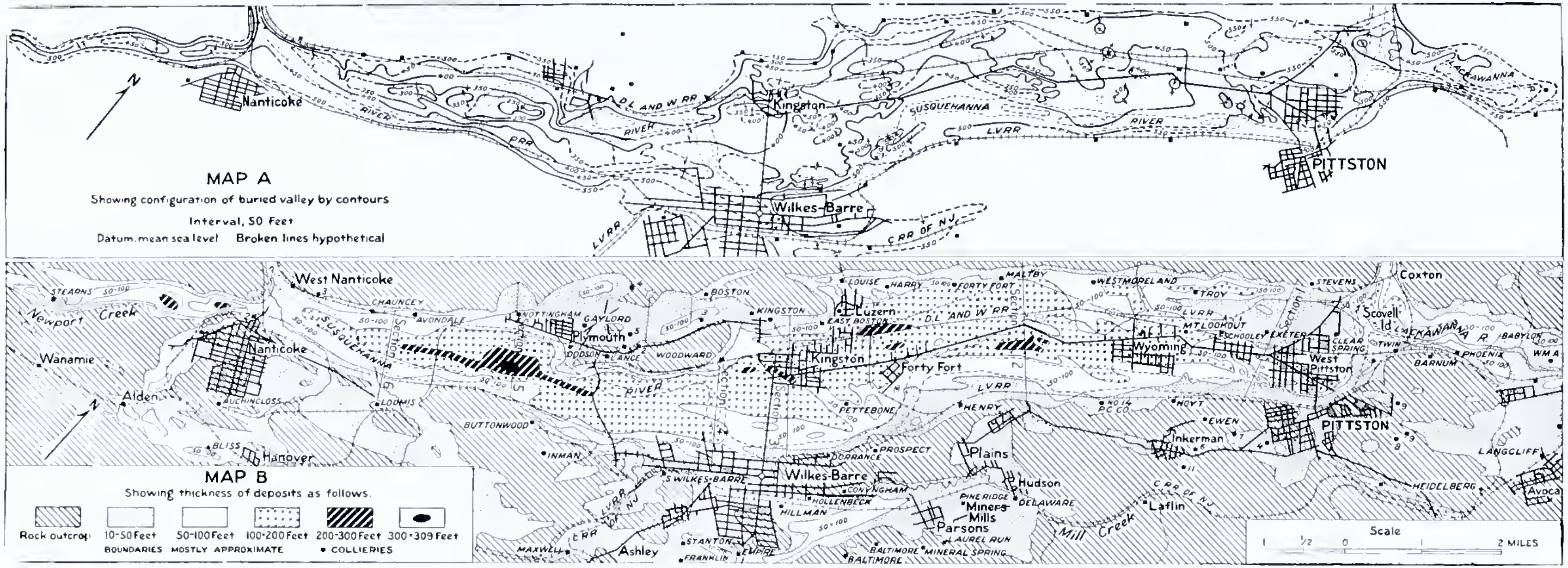


Figure 53. Map showing buried channel of Susquehanna River, Luzerne County, after Darton.

ing to Darton, pits in glacial material reveal water-laid or reworked drift overlain by 2 to 4 feet of what appears to be drift. This suggests that the eroding by ice in this area was not Wisconsin, but probably Illinoian in age. This would be in accord with the belief generally held that it was not Wisconsin ice that eroded the Finger Lake basins of New York. The material filling the valley, according to records of drill holes and shafts, is not drift, but water deposits, consisting of alternating layers of sand, gravel, and clay, each 10 to 80 feet thick. Under Kingston is a bed of clay 80 to 100 feet thick, telling of local ponding.

Besides the deep valley filling a number of terraces flank the valley and are of interest. Fairchild interpreted these as deltas formed in a lake held up by a gravel fill in the valley between Nanticoke and Shickshinny. Darton, Johnson, and Itter, from studies of the structure of these terraces as revealed in quarry cuts, conclude that they were formed by ponding of side streams against stagnant ice; and, especially, by material laid down by streams flowing between the bank and such a mass of ice left after the retreat of the glacier. This satisfies not only the river-bed type of deposit clearly exposed in the sand pits, but accounts for the varying levels at which the terraces occur. Thus the "Tilbury plain," 30 acres in extent, (Fig. 54), at

Figure 54. "Tilbury plain" near Nanticoke, a 30-acre plain opposite Nanticoke formed in the lee of the mountain. Note inclined Pottsville sandstone in background. Photo by H. L. Fairchild.

West Nanticoke is at 680 feet A. T.; terraces either side of Toby Creek come at 705 and 750 feet; at Pittston at 710 feet; at Campbell Ledge 610 feet, etc.

An interesting physiographic feature of the Wyoming basin is the double ridge enclosing it, composed of the upturned massive Pottsville and Pocono sandstones separated by the Mauch Chunk red shale. Toward the north end of the basin the Mauch Chunk becomes thin

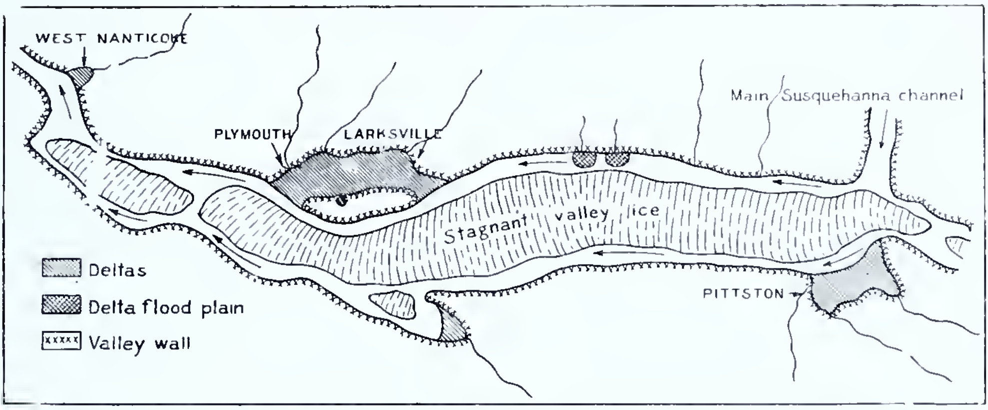


Figure 55. Diagram showing theory of development of delta in Wyoming Valley. (Itter).

and the two ridges coalesce. The structure of the enclosing ridges is well seen at West Nanticoke, (see Fig. 54), at Campbell Ledge just above West Pittston, and entering Scranton or Wilkes-Barre from the southeast.

Lackawanna Valley. (Darton, Fairchild, Itter). In the Lackawanna River Valley near Old Forge a rock terrace at 820 feet A. T. rises gently to a higher terrace near Taylor. Both are covered with a thin blanket of till. A second rock terrace at 755 feet comprises the level summits of the hills between Pittston, Duryea, and Moosic. The rolling surface has a thin cover of till. Below this level the terraces are built up of sand, gravel, and silt. Scranton lies in part on a delta of Roaring Brook at 730 to 740 feet A. T. The terrace at Avoca is at 725 to 730 feet and east of Old Forge at 720 to 740 feet. From Providence to Peckville, especially near Blakely, there are characteristic glacial deposits, including kames and eskers. Between Oliphant and Peckville there is a delta plain two miles long at 805 to 810 feet A. T.

Northwest of Archbald at the head of Tinklepaugh Creek are two notable glacial potholes. One of these, Fig. 56, has been cleaned out and shows a depth of 38 feet, a greatest diameter at the top of 42 feet in a direction N. 83°E, and a shortest diameter of 24 feet. At the bottom the hole is 17 by 14 feet. The other hole is about 1,000 feet northeast of the first. These holes are thought to be the result of streams on the surface of the glacier falling through ice crevices and impinging on the rock below.

North Branch of Susquehanna above Pittston. (Fairchild). Fairchild has noted the terraces up the Susquehanna above Pittston. Terraces underlain by gravel occur on the west side of the river at Campbell Ledge at 705 feet A. T., at 630 feet between Ransom and Falls, at 686 feet opposite Falls, and at 685 feet one and one-half miles above Falls. I. C. White* describes four terraces opposite La Grange, (a) river flood plain, (b) a cobble plain at 670 feet A. T., (c) an undulating plain with boulders at 720 feet A. T., (d) a narrow shelf at 770 feet with white clay on top. Bowmans Creek has built a large delta topped at 810 feet A. T.

* White, I. C., Geology of the Susquehanna River region: Pennsylvania Second Geol. Survey, Report G7, pp. 20-21, 135-136, 1883.

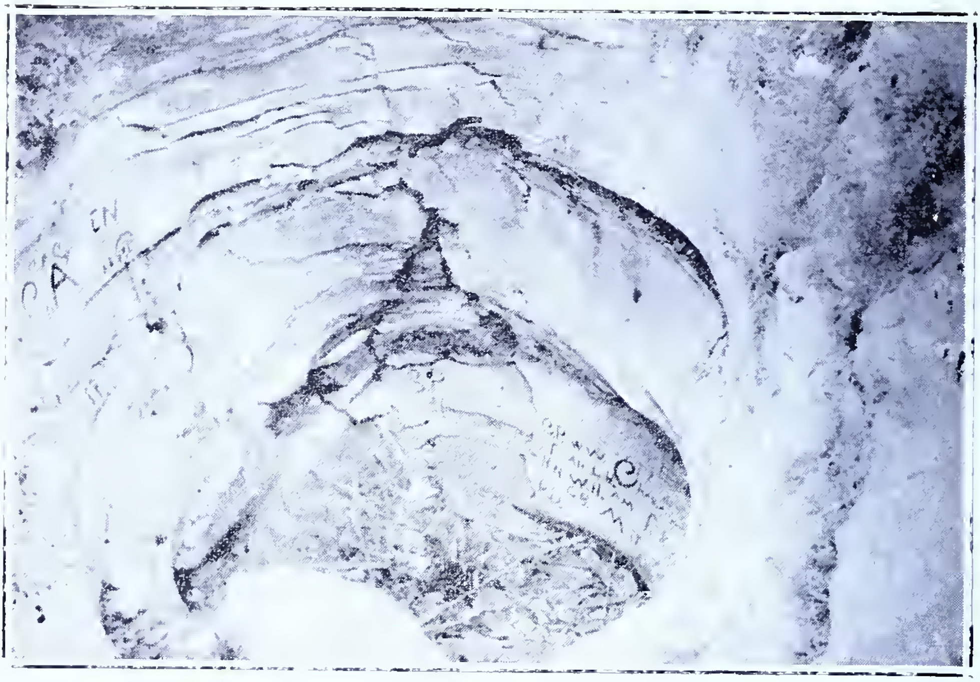


Figure 56. Looking down into glacial pothole near Archbald.

Fairchild calls special attention to the breadth of the Tunkhannock Valley and of the terraces at several levels on its flanks occurring between 690 feet and 765 feet A. T. He suggests that this creek may have the course of the early Susquehanna across Susquehanna County through a gap 400 to 500 feet deep at Jackson. As this gap is about 1,600 feet A. T., while the river terraces in the valley are only at 700 feet, and the river at Susquehanna on the north is below 900 feet, this would imply that the valley at Susquehanna had been cut down at least 700 feet since the divergence and, therefore, that divergence took place either long before the glacial age or that much cutting of the upper valley had taken place since early glacial time.

At the present time it seems more likely that the wide valley of Tunkhannock Creek is due in part to cutting by glacial waters impounded on the north side of the divide and escaping southward through the gap at Jackson, and in part to valley filling.

Good plains occur west of Laceyville at 700 feet A. T. and at Wyalusing. In the Towanda area are wide plains at 740 feet. (See Fig. 59). Extensive glacial plains occur in the Towanda Creek Valley at 825 to 865 feet. In the area above Ulster are several terraces at 875 to 900 feet. A great rolling plain north of Athens is 770 to 800 feet above sea level and rises to 835 feet at Waverly, N. Y.

The glacial features in the Susquehanna Valley in New York are not described here. The drift is deep between Great Bend and Lanesboro. Two miles above Great Bend is evidence of a glacial dam and lake from which the river escaped by a rock channel 100 feet deep and 1,000 feet long, half a mile north of the old channel, the only such rock cut on the river, according to Fairchild. At Lanesboro a delta built by Canawacta and Starrucca creeks makes a good terrace at 1,004 feet A. T. and there is an especially bold esker two miles long between Susquehanna and Lanesboro. (See Fig. 43).

Figure 57. Terraces one mile northwest of Campbells Ledge, near Pittston.

Figure 58. Tunkhannock Valley from Nicholson viaduct.

Figure 59. Plain at Towanda. Note also peneplane (Allegheny ?) in distance. Photos by H. L. Fairchild.

Figure 60. Rock cut east of Great Bend. Photo by H. L. Fairchild.

Wisconsin drift border. (Leverett).

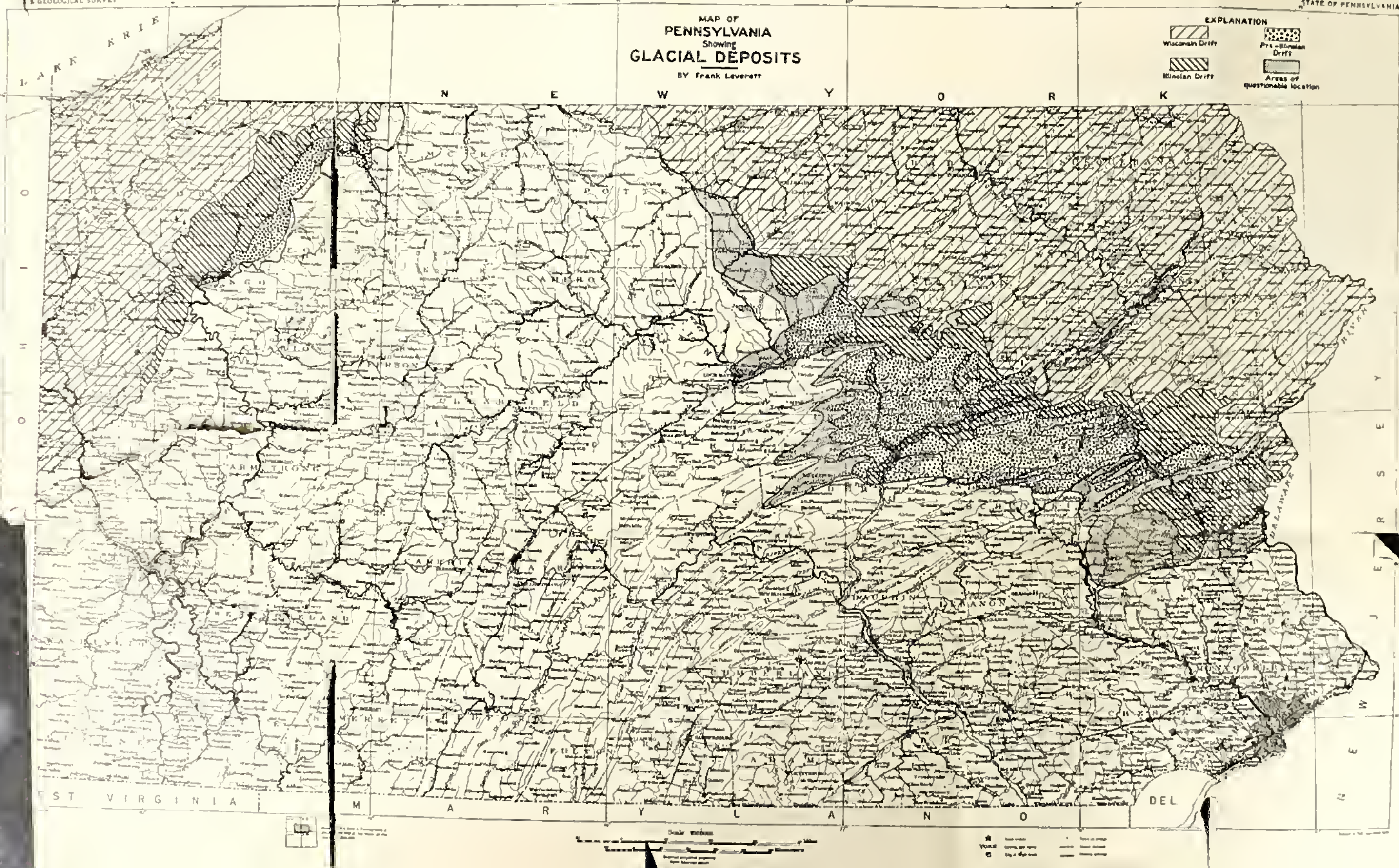
The Wisconsin drift border, as delineated by Leverett on the map here published, shows in many places more definite adjustment to the topography than in the former mapping by Lewis and Wright. He omits Wisconsin drift on some of the high points represented as covered on the Lewis and Wright map, and projects ice tongues down several valleys that the Lewis and Wright map shows as free of ice. Lewis and Wright's mapping, according to Leverett, included some Illinoian drift, as near Zehner and south of Lee Mountain.

The boundary crosses the North Branch between Berwick and Beach Haven, swings around the north end of North Mountain, down Muncy Creek to Hughesville, and attains an altitude of 2,100 feet near the west line of Sullivan County between Muncy Creek and Loyalsock Creek. It follows down Bear Run to the Loyalsock and down that creek nearly to the mouth of Wallace Run. It was not remapped beyond that point.

Wisconsin gravel trains. On the North Branch, Wisconsin gravel trains are lower than the Illinoian gravel terraces and well marked from east of Berwick to Northumberland, having an altitude of 120 feet above the river at Berwick, descending to 40-60 feet above the river at Northumberland.

Near Berwick the train is filled with large boulders (See Fig. 67), and the surface is plain. It descends to 60 feet above the river between Berwick and Mifflinville, and to 40 feet above the river at Catawissa; then follows about parallel with the grade of the river. On Fishing Creek the gravel train heads just above Benton, rising to 30 or 40 feet above the creek. The material decreases in size down stream. On Nescopeck Creek the train starts at St. Johns at about 1,000 feet A. T. and joins the North Branch at 480 feet. It does not appear as a distinct terrace.

On the West Branch there are distinct trains on the Big Muncy and Loyalsock, the latter rising to 50 or 60 feet above the creek at Loyalsock and to 540 feet A. T. at Montoursville where it is 40 feet thick and forms a broad plain. Terraces occur near Muncy at 20 and 45 feet above the river. The elevations of the main Wisconsin gravel


STATE OF PENNSYLVANIA
MAP OF
PENNSYLVANIA
Showing
GLACIAL DEPOSITS
BY Frank Leverett
EXPLANATION
Wisconsin Drift
Pre-Illinoian Drift
Illinoian Drift
Areas of questionable location
LAKE ERIE
NEW YORK
OHIO
WEST VIRGINIA
MARYLAND
DEL
NEW JERSEY
DELAWARE

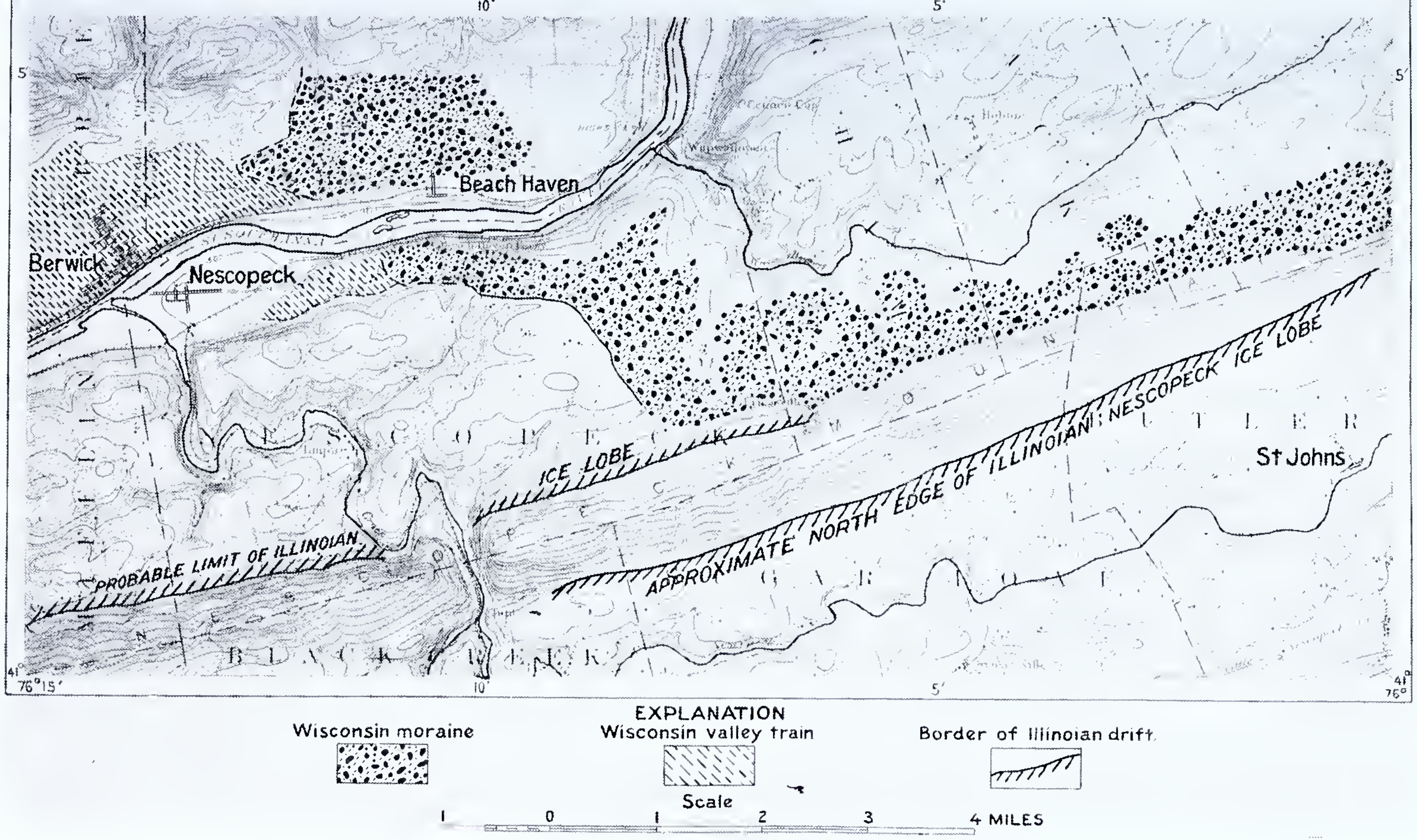


Figure 61. Glacial features near Berwick. (Leverett)

Figure 62. Roadside section of Wisconsin gravel train just east of Berwick.

Figure 63. Outwash gravel plain near Montoursville at 540 feet A .T.

train given by Leverett, based on the topographic maps, are: 580 feet at Pine Creek, 560 feet at Lycoming Creek, 540 feet at Loyalsock, 520 feet at Muncy Creek, 480 feet near Milton, 460 feet above Selinsgrove, and below that at various levels, but best defined at about 40 feet above the river. (See section based on work of Hickok and Moyer).

Illinoian drift in Susquehanna basin. (Leverett).

Previous writers have interpreted drift outside the main moraine as evidence of an early Wisconsin movement. In the Susquehanna basin, this drift occurs chiefly in the lowlands between mountain ridges as though due to lobes or tongues that projected far down the valleys, while the uncovered ridges extended back, in some places to within the Wisconsin boundary.

Figure 64. Marginal swell and sag topography, shown in the foreground, half a mile west of Selinsgrove.

North Branch of Susquehanna River. Although the edge of the Wisconsin ice was above Berwick, an Illinoian lobe extended south and west to beyond Selinsgrove with a sublobe 4 miles up the West Branch to Winfield. It was thus 40 miles long and not over 8 miles wide. The deposits are scanty on the uplands and heavy in lower places, making it somewhat hard to define the limits of the lobe. The

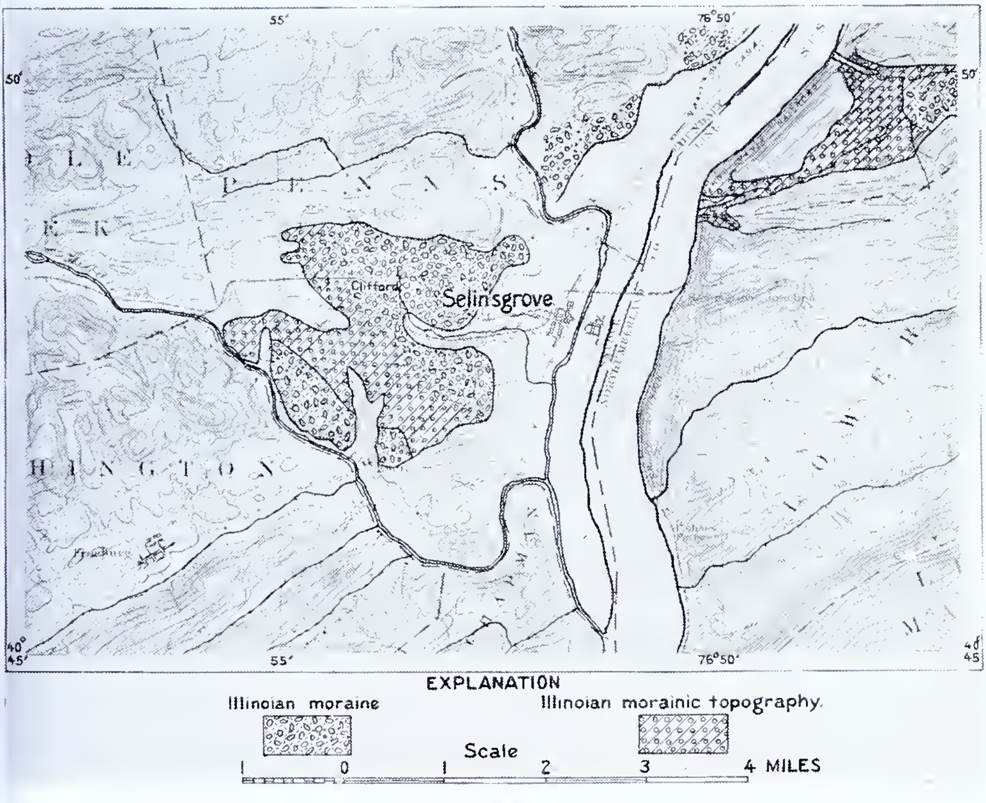


Figure 65. Illinoian drift at Selinsgrove. (Leverett)

Figure 66. Map of Wisconsin and Illinoian deposits near Montgomery. (Leverett)

lobe appears to have been only 2 miles wide below Danville. At Selinsgrove it covered ground over 200 feet above the river. The drift is found on the slopes down to within 60 feet of the present river, suggesting that the lower 60 feet of the present valley have been eroded since Illinoian time.

The drift left by this lobe is reddish clay with pockets or beds of sand and gravel. Its topographic expression is usually plain, but there is morainic topography west of Selinsgrove. (See Fig. 64)

Eight feet of this material, much decayed, is exposed in a railroad cut west of Selinsgrove. Morainic topography also occurs 3 miles south of Sunbury on the east side of the river and up to 200 feet above the river. A mild type of swell and sag topography occurs at many places. The deposits are of considerable thickness in places, as along the base of Knob and Lee Mountain, where wells penetrate 50 or 60 feet of drift. It is thinner on the south side of the valley where the ice sculptured bedrock considerably.

South of Nescopeck Mountain a lobe 2 to 4 miles wide stretching west from the Lehigh Valley extended 9 miles farther than the Wisconsin ice sheet. The drift in Nescopeck Valley is 20 to 30 feet thick. Ice also pushed westward over Greenwood Valley and down Green Creek and Little Fishing Creek, and down little Muncy Creek to the West Branch.

West Branch of Susquehanna River. Glacial till supposed to be of Illinoian age occurs in the Susquehanna Valley below Williamsport and over the lowlands south of the Allegheny Front; also in places on the Allegheny plateau outside the Wisconsin moraine. The ice appears to have passed over the Allegheny Front in southern Sullivan County and over all but the west end of North Mountain into the valleys of Muncy and Little Muncy creeks. It appears to have covered the valleys as far south as the Muncy Hills. It split at the point of Bald Eagle Mountain, one lobe following up the river to join with a lobe that came down the Loyalsock; another going west up Black Hole Creek, and a third passing south to Montgomery and over the White Deer Valley as far as Allenwood. See Fig. 66. Locally the drift deposits are 80 to 90 feet thick. Outwash gravels near the mouth of the Loyalsock are 80 feet thick, the base being 30 feet above the creek. This gravel appears to have been deposited in front of the Loyalsock lobe, and later was covered by a few feet of till from ice coming in from the east. The slope of the ice surface was from 2,300 feet A. T. on North Mountain to 800 feet at Muncy, and 600 feet below Montgomery. As on the North Branch, deposits are wanting locally, being heavy in the depressions and on some of the slopes. The deposits consist mainly of reddish clay till commonly with a plain surface, but with saucer-like basins locally.

Above Williamsport water seems to have been ponded to a level of 620 to 660 feet A. T., and there are prominent alluvial cones at the mouths of Antes and McElhattan creeks. At Jersey Shore there is an extensive cobble terrace 135 feet above the river or 660 feet A. T. that is referred to ponding. Similar deposits extend up Bald Eagle Valley to levels of 670 feet A. T. This is still well below the pass at Dix at 1,100 feet which might have served as an outlet to the Juniata Valley.

Figure 67. Illinoian outwash gravels on Loyalsock near mouth.

There are till deposits south of Muncy in the White Deer Valley and near Turbotville of uncertain age. They may be pre-Illinoian. Some of this till is very stony as far south as Dewart, with a valley train farther downstream 40 feet above the river.

Illinoian ponding in lower end of West Branch. The ice lobe from the North Branch appears to have closed the Susquehanna Valley above Northumberland and to have ponded waters to a depth of 150 feet above the present river valley, making conspicuous sand deposits, mostly within 100 feet above river level. The ponded waters appear to have escaped around this lobe by passing westward into Penns Creek Valley from whence part of the flow may have followed the edge of the ice and part crossed over to Middle Creek, and thence back to the main valley.

Illinoian gravel trains in Susquehanna Valley. Deposits interpreted as valley trains of Illinoian age appear below the limits of the Illinoian drift. At Fishers Ferry, 2½ miles below Selinsgrove, such a train lies 150 feet above the river, but within a few miles is down to 120 feet above the river and from there continues at about 100-110 feet to the head of the gorge at Turkey Hill. The rock shelf or shelves upon which this deposit lies range from 60 to 100 feet above the

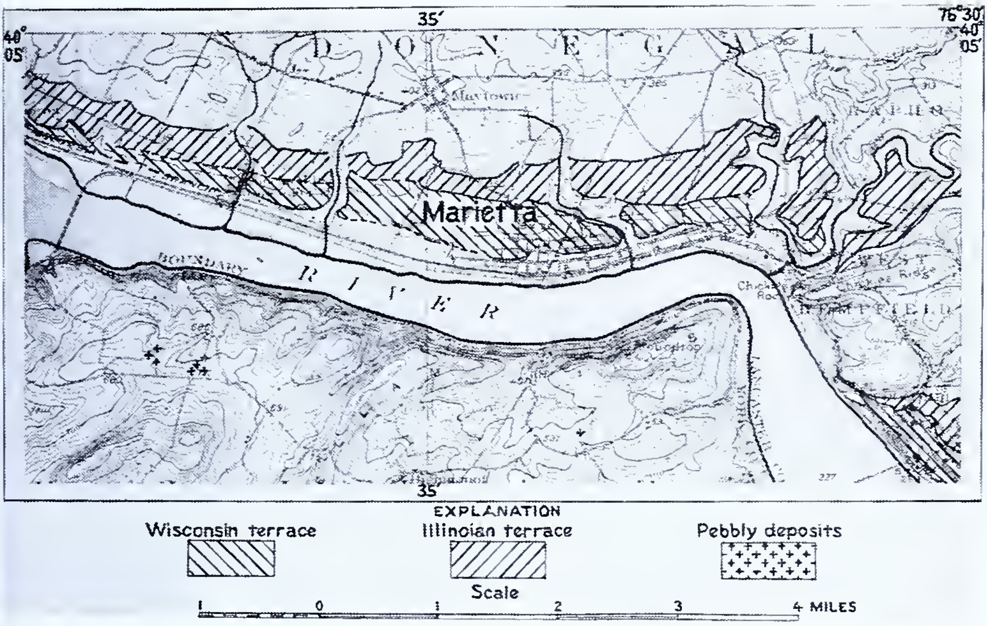


Figure 68. Terrace deposits in the vicinity of Marietta. (Leverett)

river. Probably the valley was filled to 110 feet above the present river level. Deposits are scarce through the gorge, but seem to follow about with the river gradient and to correspond with the Wicomico shore line at the head of Chesapeake Bay. Deposits at Peach Bottom and above Conewago at 70 to 80 feet above the river may be correlated with this gravel train. (See paper by Mackin).

This gravel train, though largely of local rock material, everywhere contains granite and gneiss pebbles, usually less than 4 inches in diameter, and probably making up not more than 1 per cent of the total.

Illinoian fluvial plain on the Juniata River. Gravel-covered terraces are abundant on the Juniata. Those correlated as of Illinoian age are in the main from 100 to 120 feet above the river, though ter-

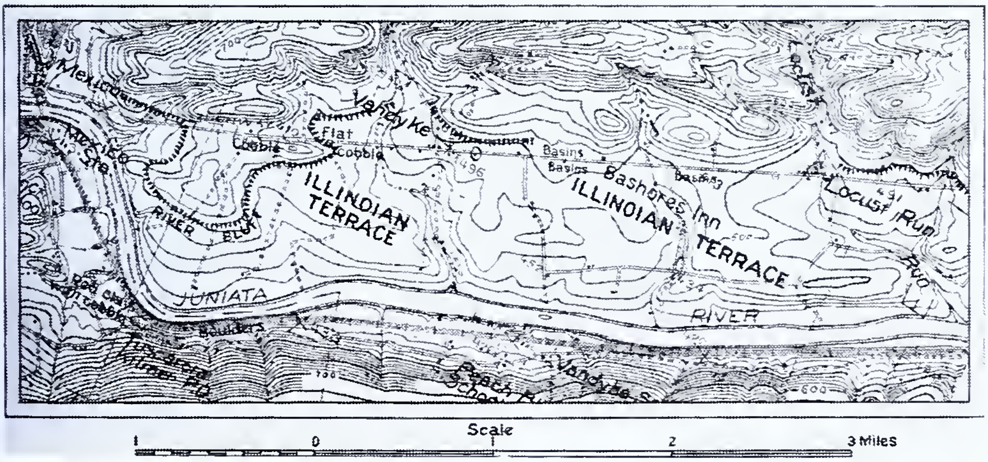


Figure 69. Illinoian terrace on the Juniata below Mexico, Juniata County. (Leverett)

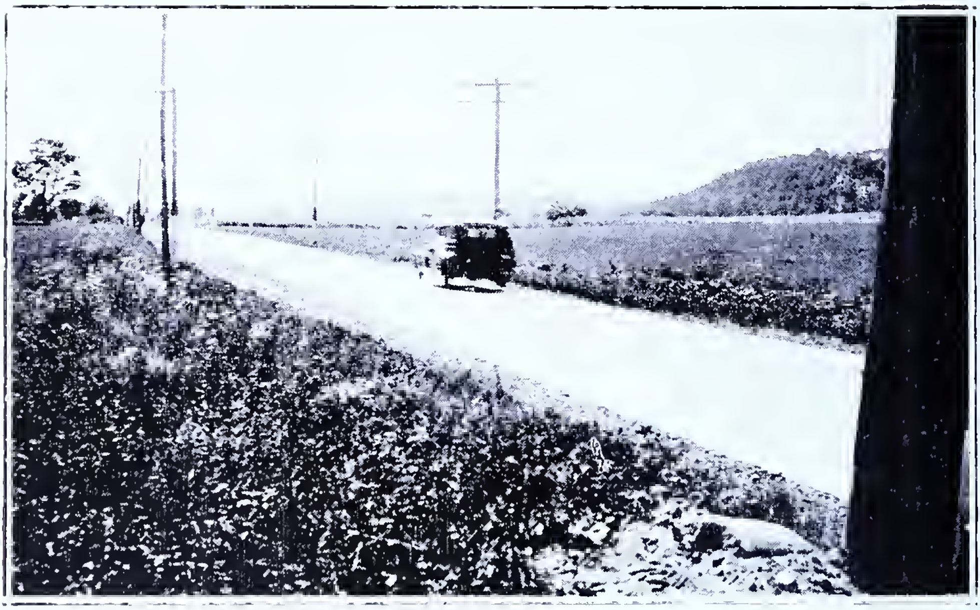


Figure 70. Illinoian gravel plain east of Thompsontown, Juniata Valley.

races at 140 to 160 feet around Mount Union and Lewistown may be of this age. In places these terraces are underlain by more than 50 feet of gravel deposits. Similar patches of gravel occur locally 60 feet or more above the streams in Clearfield County and elsewhere.

Pre-Illinoian drift in the Susquehanna basin. (Leverett).

Scattered erratics and patches of till far outside the Illinoian ice give evidence of an earlier ice advance. The scanty evidences were discovered by E. H. Williams and his assistants over 30 years ago.* These scattered erratics show few Canadian rocks, but many rocks transported far from their outcrop. It is uncertain how much of this scantiness is due to subsequent erosion and how much to the thinness of the original deposit. Though there are some evidences of two advances, for the present the deposits will be assigned to one period.

The boundary as shown on the map is more or less hypothetical, partly because of the scantiness of the material and partly because of the uncertain origin of some of the material.

In the Hazleton district there is a sheet of drift usually 10 feet or less thick, at an elevation of 1,700 to 1,800 feet. This has little or no Canadian material and but few striated rocks, but the till otherwise is fairly characteristic. Near Freeland this till reaches 1,900 feet, but seems to be lacking on the higher hills. In Black Creek Valley coal mining has exposed glacial deposits 20 to 60 feet thick with striated pebbles.

The ice crossed over the headwaters of Catawissa and Mahanoy creeks into the headwaters of the Schuylkill. The direction of flow can in places be traced by the lines of coal stretching from some outcrop. At Morea there is a surface of the Mammoth bed planed off for a quarter of a mile and overlain by 8 to 15 feet of drift at an

* Williams, E. H., Pennsylvania Glaciation, First Phase, 1917.

Figure 71. Mammoth coal bed at Morea planed off by ice and overlain by early glacial till. Photo by E. H. Williams, Jr.

elevation of 1,500 feet. Deposits near Frackville, Locust Summit, Big Mountain and north of Shamokin appear to be of glacial origin.

Patches of till and scattered erratics occur on both sides of the West Branch of the Susquehanna between Northumberland and Watsontown. In the Sunbury-Muncy region boulders and cobbles rise from 600 feet A. T. at the south to 800 feet on the Muncy Hills. The movement is thought to have been southward over the Allegheny Front. West of the river the drift is very scanty, though here and there are patches of what appear to be till, notably two miles west of McClure in Mifflin County where there is 80 feet of material probably of glacial origin. Glacial till is present between the Allegheny Front and Susquehanna River from Lycoming Creek past Larrys Creek, and up to 1,100 feet altitude. In many places stony clay is found too far from the mountains to be classed as talus.

Williams assumed that ponding has occurred in the Williamsport region in the valleys leading toward this early ice, and that the water thus ponded, which he called Lake Lesley, escaped through the Bald Eagle Valley and Middle Creek Valley to the Juniata. An examination of the col at Dix and just west of McClure failed to find evidences of such outflow, but the valleys are so well filled with talus, and at Dix by outwash from the near-by mountain, as to obscure positive evidence. Big Fill Run above Tyrone brought in such a volume of material as to dam up the valley and produce a lake three miles long. Clays laid down in this lake still show on the flanks of the valley. Later the dam was breached at one end.

Water worn pebbles and cobbles have been found near the Susquehanna on the hilltops reduced from the Harrisburg peneplane, that are now 200 feet or more above the river. These pebbles are not conspicuous, but occur on nearly all the level lands facing the river at that elevation. Most of these pebbles are less than three inches in

diameter. A cobble of schist, described by Prof. W. F. Hunt of University of Michigan as "metamorphosed quartzite" 9 by 7 by 5 inches in diameter, so decayed it crumbled in the hand, was found on the upland one mile north of Dauphin at 500 feet A. T. It may have come from a conglomerate in the underlying Mauch Chunk, though no corresponding rocks have yet been recognized in those conglomerates. If it did not so originate, it suggests that the Harrisburg peneplane on which it was found is of post-Tertiary age, and probably corresponds with the early ice advance under discussion.

High level gravels in Chambersburg region. (Ashley).

Additional evidence of a period of unusual erosion and transportation is found in the Chambersburg portion of the Appalachian Valley, as shown in the Mercersburg-Chambersburg folio, by Stose. In that area are many hilltops covered with gravel, evidently outwashed from the mountains on the east and west, but now separated from the mountains by intervening valleys up to 100 feet deep. The extent of this wash, in places reaching 6 miles from the foot of the mountains, would suggest climatic conditions such as might have accompanied glaciation farther north, while the depths of subsequent erosion would seem to put the time early in the Ice age. Indeed, the writer has suggested the examination of these gravels for evidence of glaciation (mountain type). Examination by C. K. Wentworth failed to reveal any faceted or striated pebbles to confirm this theory.

As shown on the maps of the Mercersburg-Chambersburg folio, there appear to have been two periods during which gravels were deposited widely along Conococheague Creek, a fairly recent period in which gravels reach a uniform elevation above the creek of 70 feet with a bottom limit of about 30 feet, and an earlier deposit in which the highest part of the deposit is from 100 feet at Scotland to 170 feet near Williamson. The exact age of these gravels has not been established; but the suggestion that both express conditions during glacial time suggest early and late glacial time. This would seem to be in agreement with the writer's estimates for the Harrisburg and Sumerville peneplanes judged by the extent to which the valley has been excavated below the base of the gravel. Near Chambersburg, the older gravel lies on the Chambersburg peneplane, and was thought by Stose to be of that age but the fact that it is found at levels below the level of the Chambersburg peneplane indicates it is of later age, probably Bryn Mawr. Again we are facing a problem that offers unlimited room for study.

Low terraces on the Susquehanna from Lock Haven to Turkey Head (Hickok and Moyer)

One of the most interesting problems facing man today is: "How old is man?" Discoveries in all parts of the world are carrying the history of man farther and farther back. It is no longer a question of thousands of years but of scores of thousands or even hundreds of thousands of years. In nearly every discovery of very ancient human bones or artifacts there arises the question "just how old are these finds?" Many of them occur in river deposits. To answer this ques-

tion accurately demands accurate knowledge of the history and age of river deposits. Every careful study of such gravels, leading to a better knowledge of them, throws some light on the general problem. This is one of the reasons for undertaking the survey of low terraces.

Only a preliminary statement of the work by Hickok and Moyer can be made at this time for three reasons: First, because the data now available will require large scale charts and maps to accompany its discussion (the field maps being on the scale of 1,000 feet to one inch).

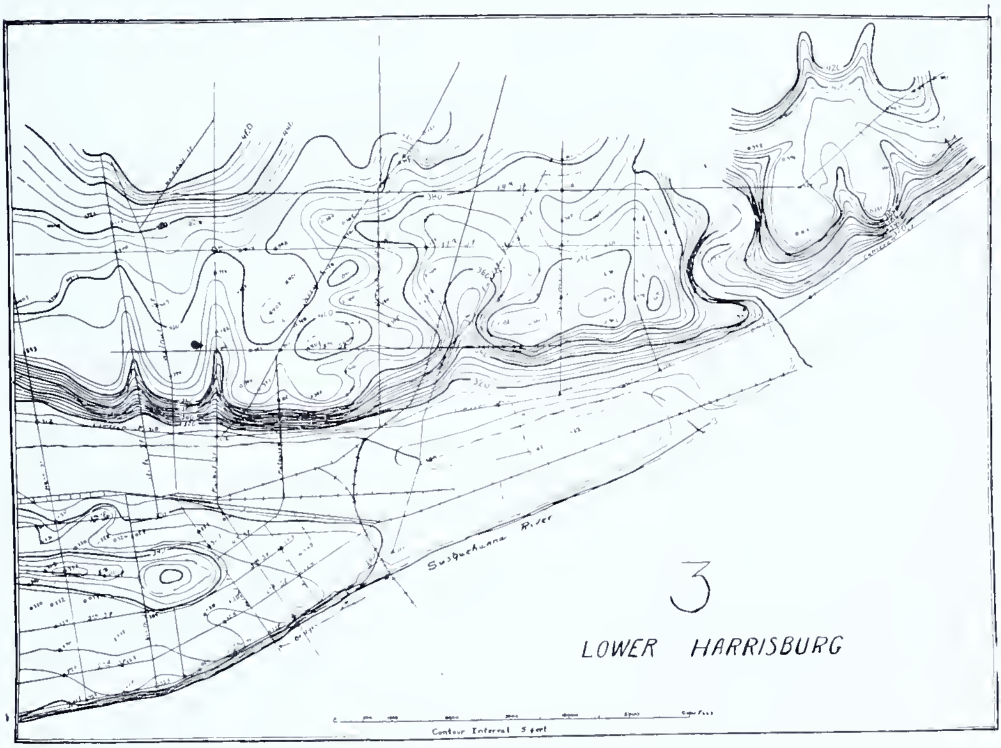


Figure 72. Portion of field map of terraces along the Susquehanna in south part of Harrisburg. (Hickok and Moyer)

Second, much additional work is needed to arrive at definite interpretations of the results; and third, because the higher terraces need to be fitted into the picture. Figure 72 illustrates on reduced scale the topographic base being made as a foundation for a study of the river terraces and their gravels. This is typical of the second stage of such a study, of which the work of Fairchild and Leverett illustrates the first, or reconnaissance stage.

These terraces range from 100 feet or less to a mile or more wide. Terraces usually are developed only on one side of the river at any one place but occur locally on both sides. They are of two types: those with only a slight covering of gravel or none, and those formed of river deposits 10 or more feet thick. (See Fig. 73) The latter type consist commonly of sand and gravel at the bottom, sand making up the bulk of the deposit, and silt at the top, or gravel and sand may occur irregularly all through the deposit. The content of such a terrace may vary rapidly from place to place. Usually the deposits are thickest on the edge toward the river and thin to nothing away from it.

Figure 73. Surface of terrace near Harrisburg 100 feet above the river. The deposit underlying this plain is about 20 feet thick on the river side and thins to a feather edge away from the river.

As a rule the low terraces are gravel covered, whereas gravel is scanty or lacking on the upper terraces. Further, lower terraces as a rule are wider or more continuous than the higher, largely because they are younger and therefore less eroded than the higher terraces. The number of terraces and their discordant elevations suggest that many of them represent only local effects of erosion and deposition by a river rapidly deepening its valley and constantly shifting the position of its channel. Obviously, the lower terraces do not compare in lateral extent with the broad erosion surfaces, in areas of soft rocks or limestones, not river cut, that lie 125 to 250 feet above the river and are correlated with the Somerville and Harrisburg peneplanes.

Between Lock Haven and Muncy there is an almost continuous bench 20 to 40 feet above the river, in some places a mile or more wide. Locally, later river cutting into this terrace has produced benches at a lower level. Above that are many terraces or terrace remnants, but they lie at discordant levels. In the Williamsport and Montoursville areas there are a number of broad flats 30 to 60 feet above the river. See Fig. 68.

Northeast and southwest of Muncy an area of many square miles, extending east to Hughesville, comprises several flats at about 20, 45, 90, 125 and 155 feet above the river. East of Dewart and Watsontown, in addition to terraces at 30, 45, and 120 feet above the river, there is a broad area extending east to Washingtonville and lying between 50 and 150 feet above the river that is still to be interpreted in terms of the river terraces. At Lewisburg are broad flats 20 to 30, and 40 to 60 feet above and on both sides of the river, and limited hilltops 95 and 140 feet above the river. At Sunbury are extensive flats 440 and 500 feet A. T., or 25 and 85 feet above the river. From Shamokin Dam past Selinsgrove the lower terrace continues, with other terraces 20 and 50 feet higher and numerous moraine-covered hilltops 200 feet above the river. From Selinsgrove to Rockville the valley is narrow with

only narrow and generally inconspicuous terraces. In places silt and gravel terraces occur within 25 feet of the river. On Haldeman Island at the mouth of the Juniata are broad terraces 15, 35, 50, and 85 feet above the river. At Harrisburg the principal terraces are 25, 45, 75, and 105 feet above the river. Farther down the river the most prominent plains are 20, 50, 80-90, 110, and 125 feet above the river. From York Haven to Chickies the terraces are pronounced on the east side of the river at 30, 80, 95, 130, and 170 feet above the river. The last probably is at the level of the Somerville peneplane. In the York-Columbia Valley the principal terrace is 140 feet above the river.

At places the river gradient drops sharply, as below Loyalsock Creek, north of Montgomery, at McKees Half Falls, Dauphin and York Haven. At these points, sometimes called "knickpoints," there is some evidence of lower terraces running into the river and of new terraces beginning at the flood plain and rising gradually above it downstream. These knickpoints have been studied to determine if they represent stages in the headward progress of the river gradient or occur at points where harder rocks across the channel resist river deepening. Associated with that question is one regarding the low terraces: "Does the lowest terrace below such a knickpoint correspond with river level above the knickpoint?" These are a few of the points still at issue. This study has revealed a mass of detail that can only be properly discussed in connection with large scale maps and sections.

Lower Susquehanna gorge. (Fairchild, Campbell, Mackin, Mathews.)

Fairchild called attention to the change in gradient of the Susquehanna at Turkey Hill. The river above that point has an average gradient of a little over 2 feet to the mile, while below that point the gradient is over 6 feet to the mile. This is assumed to be the result of a recent uplift which of course renewed the river's cutting power. The steeper grade indicates the extent to which cutting its channel down to sea level by the river has progressed.

The character and structure of the rock has resulted in a long stretch of rapids rather than a waterfall plunging into a gorge with a receding head, as at Niagara, and in a narrow gorge in which the terraces which are prominent farther upstream never were developed. Waterworn pebbles occur on the shoulders of the hills in a few places. In contrast with the narrow gorge the uplands back from the river are rolling, with gravel-covered hilltops.

Apparently these gravels, sands and clays are of preglacial age. The oldest of these, believed to be Cretaceous, largely red and white clays, has been found in only a few places. These range from sea level east and west of the mouth of the river to 450 feet at Woodlawn, only a few miles to the north. This apparent rise to the north is interpreted as indicative that these small rock exposures lie on the erosion surface of pre-Cretaceous age that plunges below drainage level along the Delaware with an average southeast gradient under New Jersey and Maryland, of 75 feet to a mile. This surface, if projected north over Pennsylvania, would pass high above the present mountains of the State. This is one of the peneplanes previously referred to, that, sunk below sea level, covered with a blanket of deposits, then raised above sea level, served as a bed for Pennsylvania's baby rivers. Which of

these uplifted plains cradled the beginnings of the rivers of today is not yet known.

Later peneplanes now have lower grades as they pass below sea level and support deposits of Tertiary age in Maryland and New Jersey. Gravels of Tertiary or Quaternary age occur at several levels either side of the lower Susquehanna, extending north into Pennsylvania. In several places these lie on the Cretaceous clays, rising, as shown by Campbell, to 660 feet near Conestoga Creek. Campbell believed that this rapid rise was on the south flank of what he called the Westminster anticline. Northward, gravels are found at lower levels which he interpreted as a descent on the north side of the anticline.[*]

Mackin's report traces and describes the "Illinoian" and other terraces. He ascribes the Illinoian terrace to "late Somerville" time.

Figure 74. Terrace plains near Marietta.

Figure 75. Susquehanna River bed near Fites Eddy showing the rocky character, before submerged by the Conowingo Dam, and indicative of the rapid downcutting of the river bed.

[*] Campbell, M. R., Late geologic deformation of the Appalachian Piedmont as determined by river gravels: Nat. Acad. Sci., Proc., vol. 15, no. 2, pp. 156-161, February 15, 1929.

He shows that there is an almost continuous terrace from Harrisburg to Wrightsville, except for a break between Middletown and Billmeyer. The elevation as determined by him, with Hickok and Moyer, is 404 to 408 feet at Harrisburg, 390 to 395 at Steelton, 394 at Highspire, 365 to 375 at Shocks Mills, where the terrace is three-quarters of a mile wide, 345 to 360 feet at Wrightsville. He notes that it passes the knickpoint at Falmouth without appreciable discordance, and concludes that the knickpoint is the expression of two resistant barriers rather than of a wave of rejuvenation.

Figure 75A. Deep channel cut below general level of bed of Susquehanna River at Safe Harbor. Exposed when river was diverted in connection with building the Safe Harbor dam. Photo by R. W. Stone.

Mackin attempts to determine the gradient of such a terrace through the gorge by projecting into the line of the river the low gradients of the main stream and of the several side streams. As with the main stream, the side streams have low gradients on their upper waters but steep gradients where they are cutting down to the deepened level of the river in the gorge below Turkey Hill. He finds at the mouths of the several side streams close concordance between the elevation of the projection of the low gradient of the terrace above Columbia through the gorge with the elevation of the projection of the side streams. These indicate that were this terrace continued into the gorge it should have an elevation of about 300 feet A. T. at McCalls Ferry, or nearly 200 feet above the river bed at Holtwood Dam. This is a measure of the deepening of the river which has taken place since Somerville time at that point. Leverett found gravels in the Holtwood region at about 538 feet A. T., which might correspond with the gravels found at many points farther north and correlated with the Harrisburg peneplane. The whole subject is one requiring further study for its solution.

"Deeps" on lower Susquehanna. (Mathews).

Drilling to disclose bedrock conditions in connection with the building of the Holtwood Dam revealed a series of deep holes in the bottom of the river. These have been described by Mathews.* They occur 1.6 miles above Safe Harbor, above and below McCalls Ferry and elsewhere down to Conowingo.

These "deeps," as they have been called, are up to 2 miles long and 125 feet deep, and range from 150 to 400 feet wide. They are generally close to the east bank of the river. The walls and bottoms are very irregular and roughened by vertical potholes. They show a general tendency to be deepest upstream and to spoon out or become shallow downstream. Mathews suggested their origin as cutting by a river of large volume running in a constricted channel.

Drilling in the river bed at Harrisburg on the line of the Reading Railroad bridge disclosed a "deep" containing up to 45 feet of sand and gravel. At Harrisburg the river is 0.9 of a mile wide and very shallow. This hole is in limestone and may be due to differential solution. The north edge of this belt of limestone crosses the river diagonally, and it is said that at this edge a channel of some depth existed and was used by the John Harris ferry in crossing the river at low water, illustrating again how some seeming trivial natural condition may determine history, in this instance the location of the Capitol of a great State.

Correlations across the Piedmont. (Ashley)

Deep, narrow valleys across the Piedmont area are unfavorable to the existence or preservation of terraces and this has rendered uncertain the correlation of some of the surface features north of the Piedmont with those to the south.

North of the Piedmont there are thought to be traces of at least four widespread erosion surfaces formed during periods of long standstill in the general movement of uplift and two or more levels associated with the disposition of gravel. In addition are evidences of at least three advances of the glacial ice. South of the Piedmont are the deposits of Cretaceous and later age dipping southeastward under New Jersey, Delaware, and Maryland, and certain widespread continental deposits, now deformed, and raised beach deposits that cover most of the land between Chesapeake Bay and Delaware Bay and the ocean.

References have previously been made to data thought to indicate that the Schooley peneplane might correlate with the surface under the Kirkland formation of New Jersey of pre-Middle Miocene age. It is probably not older than that and may be younger. The Allegheny (Sunbury-Chambersburg ?) peneplane appears to coincide with the Schooley on the south flank of the Piedmont region where it comes in contact with the coastal plain deposits. As pointed out elsewhere the uplift of this area may have been very recent. In general the age of that plane is commonly thought to be Late Tertiary, though it may prove to be very early Pleistocene.

The Glacial age appears to have been a time of great crustal unrest. It is now generally recognized that most, if not all, of the

* Mathews, Edward B., Submerged "deeps" in the Susquehanna River. Geol. Soc of Amer., Bull. 28, pp. 335-346, 1917.

highest mountains of the world obtained their present elevation as the result of movements in glacial time or immediately preceding. In part, these crustal movements of Glacial age may be ascribed to ice loading, in part to water withdrawal from the sea or its return during the accumulation or melting of the ice, and in part to the normal movements of adjustment constantly in progress in the earth's crust.

It is not possible at this time to give the exact sequence of events. It is probable that the uplift toward the northeast of the old raised beach lines along Lake Erie, referred to elsewhere, was due to the rise of the land in the eastern Great Lake area following unloading after the retreat of the ice. It has also been generally assumed that the flooding of northeastern United States to a depth of 600 feet which left marine shells and bones of whales and seals at 440 feet above the present surface of Lake Champlain came immediately after the retreat of the Wisconsin or Laborador ice and before the crust had had time to rise and readjust itself. That flooding decreased southward and it is said to have amounted to only about 90 feet in the Hudson Valley at New York City. On the other hand, at one time the coastal area seems to have stood much higher than today as is indicated by the channels extending out from the mouths of the Hudson. Delaware, and Chesapeake bays across the continental shelf for 100 miles or more and to a very considerable depth. These channels have sometimes been correlated with the deep rock channel of Hudson River. While the Hudson Valley has been deeply scoured out, the Susquehanna and other rivers of eastern Pennsylvania have not been cut below their present river bottoms as they are still running on rock above the "fall line." It was long ago suggested* that while the area under the ice was being depressed by the weight of the ice, the area outside might have been elevated just as a marsh bulges up either side a railroad embankment crossing it. It hardly seems possible, however, that this explanation would account for the elevation of the continental shelf so far away as the mouth of Chesapeake Bay. Again, though not proved, it is highly probable that the great depth of erosion of the Hudson through the highlands (to more than 765 feet) is due to ice scour, probably in Illinoian time, as the Wisconsin ice seems to have crossed this channel diagonally.

Recent studies by Campbell, Leverett, and others, added to our previous knowledge, indicate that probably early in glacial time conditions, whether associated with the ice or not, favored the laying down of widespread gravel deposits forming alluvial fans at the mouths of rivers and streams, laid down on a very old peneplane surface.* These gravels, formerly called the Lafayette gravel, are today called the Bryn Mawr in Pennsylvania, the Brandywine in Maryland, the Pensauken and Bridgeton in New Jersey. Apparently, though not known, these are all the same, the deposit having been deformed after its laying down. If they are the same, the name Bryn Mawr having precedence in time might well be applied to the whole. Apparently at that time the drainage of all or nearly all of northern New Jersey flowed southwestward past Somerville, Princeton, and Trenton to the present lower Delaware. It is not clear what

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* Jamison, T. F., Geol. Mag., vol. 21, p. 179, 1860, and vol. 9, p. 461, 1882.

* Campbell, M. R., Alluvial fan of Potomac River: Bull. Geol. Soc. Am., vol. 42, pp. 825-852, 1931.

the condition of the present Delaware above Trenton was at that time. Campbell points out, however, that it appears not to have produced an alluvial fan, or, if it did, it was swallowed up in the deposits of the larger river running past Princeton. This drainage may have included the drainage of the upper Delaware and Hudson rivers. The detached upland gravels of Franklin County may belong to this time; as well as gravel found mantling the flanks of many valleys at about 60 feet above sea level in the plateau area of the State. Later, as pointed out by Campbell, this deposit in the Delaware region was deformed being lifted southeast of a line from Somerville, New Jersey to Philadelphia, to levels of 180 feet above sea (the Bridgeton formation) and to the northwest to form the Bryn Mawr formation. The Glacial age in New Jersey seems clearly attested by the material found in it. Under the name Brandywine, it is classed as glacial in age on the recently issued geological map of Maryland. Then comes the question with which of the gravel deposits north of the Piedmont does this formation correlate? This problem is still open. Accepting Campbell's idea of an arch centering in the axis of the Piedmont area of Pennsylvania and Maryland, the Bryn Mawr after rising sharply on the south side of the arch descends toward the north to an axis in the Appalachian Valley and is now thought by Campbell to correlate with the gravels and scattered boulders on what was originally the Harrisburg peneplane, which, based on other evidence, has been thought to be of early Glacial age. Further evidences of this very recent uplift of the Piedmont region is found in the narrowness of many of the ravines in this region, typified by Wissahickon Creek near Philadelphia which has the earmarks of a post-glacial valley.

Future studies may show: (1) that the Bryn Mawr correlates with the gravels in the north side of the Hellam Hills at 750 feet and therefore is older than the Harrisburg peneplane. The cementation of the Bryn Mawr (Brandywine) gravels with iron in many places in Maryland gives them a resemblance to the cemented gravel on the Hellam Hills, and the elevation lessens the need for assuming a down bend in the limestone valley region; or, (2) the Bryn Mawr may prove to correlate with gravels of Illinoian age on the Susquehanna, in accordance with Campbell's first conclusions.

Of later age than the Bryn Mawr are the terrace deposits that mantle all of Delaware and much of eastern Maryland as well as the Delaware Valley between Trenton and Philadelphia. In Maryland these have been listed as the Sunderland, Wicomico, and Talbot formations. In New Jersey only the Cape May formation has been recognized. If the Pensauken is the correlative of the deposits originally on the Harrisburg peneplane it would seem that the deposits found on the Susquehanna at about 100 feet and at 20 to 30 feet above the present river might correlate with the Wicomico and Talbot respectively. For the present this is purely surmise. If that surmise is correct, it would imply that the Wicomico is about of Illinoian age and the Talbot of Wisconsin. The writer sees no insurmountable difficulties for the solution of these problems, but it will require very detailed, patient work in the field and an attack from several angles.

Here again the reader must realize that many of these physiographic problems are far from being settled. He should also realize that the difficulties in the way of their settlement are tremendous, remember-

ing that rock exposures are few and far between, that land deposits such as we are dealing with here vary from place to place even a few feet apart. But these difficulties serve as the greater incentive to those whose minds are set on the discovery of the truth.

GLACIATION IN WESTERN PENNSYLVANIA. (LEVERETT)

Drainage changes within the Wisconsin ice area

Confining attention to the physiographic features only, matters of most importance are the drainage changes, the formation of lake basins, and the terraces along Lake Erie. Lack of sufficient drilling to reveal the contour of the rock channels leaves many uncertainties as to the preglacial drainage of the area (see Fig. 36).

It is clear, however, that the present upper Allegheny formerly ran northwestward in several parts to the Lake Erie basin. The advance of the ice closed these northwest outlets, damming the water until it was diverted southward from one basin to the next around the front of the ice. This divergence lasted long enough to allow cutting of channels across the several divides. Compare, for example, the wide, old valley at Warren, with the narrow valley east of Glade where the river cuts through an old divide.

Likewise, the old Ohio River ran northward up the Beaver Valley and down the Grand River Valley in Ohio. In the Pittsburgh-Beaver area the old river channel was about 200 feet above the present level. The present divide between the Beaver and Grand valleys lies on a deep filling in the old channel. The advance of the ice southward ponded the waters far up the Monongahela River and down the present Ohio until they overran the edge of the basin of that day near New Martinsville. Whether all these changes took place at the time of the Illinoian advance or at the time of some earlier advance is not clear. Leverett thinks there may have been a temporary divergence as a result of the earlier advance, but that this did not become permanent until the Illinoian advance.

Between the time the Ohio was diverted and the coming of the Wisconsin ice the river channel and adjoining valley was cut down more than 200 feet. As a matter of fact, the Allegheny at Pittsburgh is running over a gravel filling in its bed, so that the downcutting was much more than is expressed by the difference in elevation between the older river channel and the present river surface.

The old channels of the Allegheny, Monongahela, and other rivers were much more winding than the present streams, the old wide channels crossing and recrossing their present channels. These old channels are today deeply filled with gravel and sand, and on the Monongahela the coarse material is covered with silt laid down while the waters were ponded.

In addition to these changes in the major drainage a multitude of minor changes occurred. Topographic maps of Youngsville, Titusville, Union City, Townville, Cambridge Springs, Meadville, and adjoining areas show a web of intercommunicating valleys, through valleys in which streams running in opposite directions rise in the same swamps with no appreciable divide. Corry is on a divide of this kind. Formerly a stream flowed westward directly across the

site of the city. Wherever a stream heads in a wide, flat valley it is almost certain that at one time the valley was occupied by a through stream of considerable size.

Space does not permit going into detail. This drainage has been discussed in a general way in a thick volume by the U. S. Geological Survey as Monograph 41, Glacial Formations and Drainage Features of the Erie and Ohio Basins, by Frank Leverett. For details of this

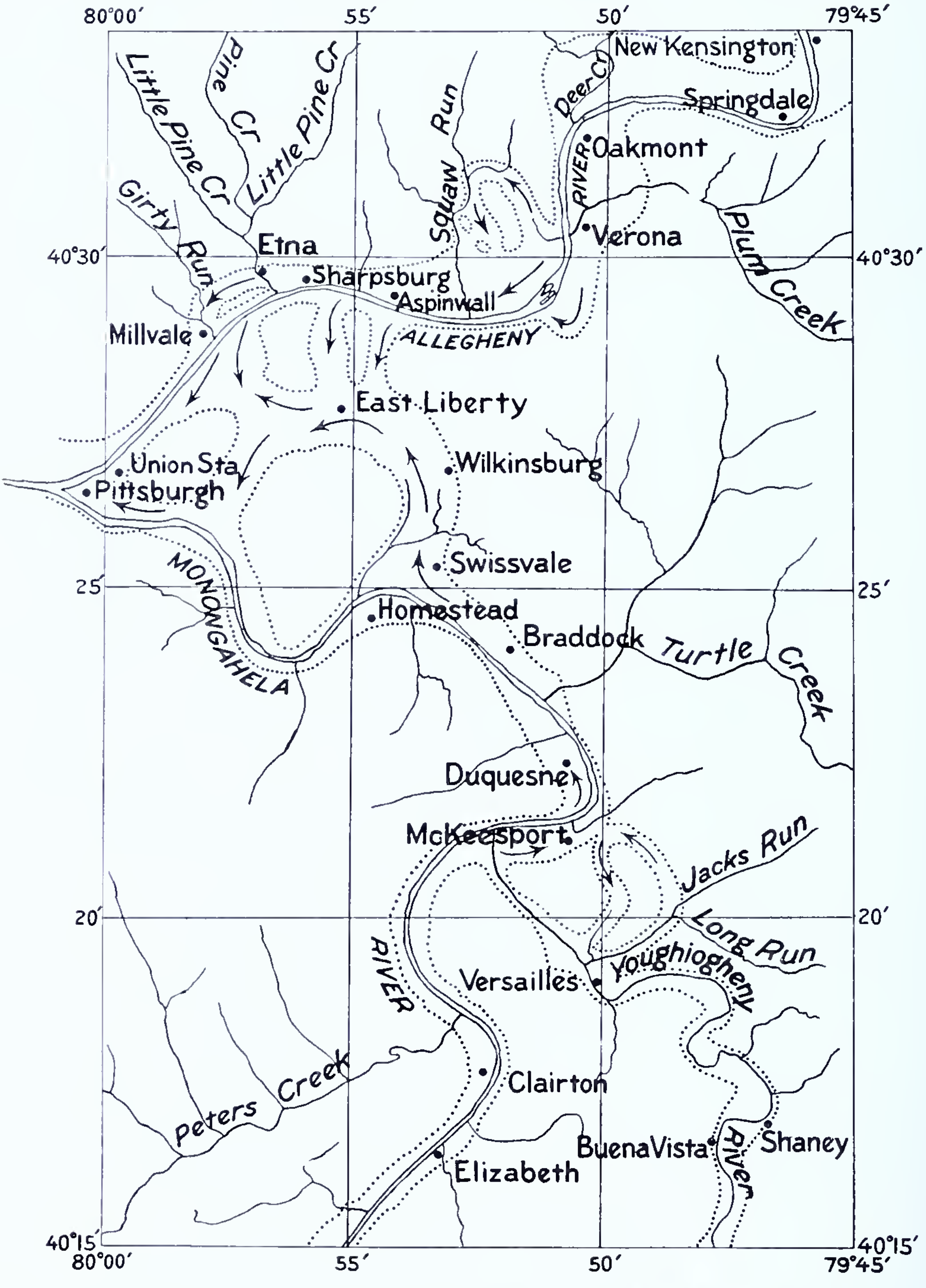

Figure 76. Sketch showing preglacial river channels on Monongahela River (dotted) 200 to 300 feet above the present river. Johnson and Leverett.

Figure 77. Ravine at Schenley Park, Pittsburgh cut below old channel of Monongahela River since it was abandoned by the river. The upland level (bridge level) is the silt-covered bed of old channel.

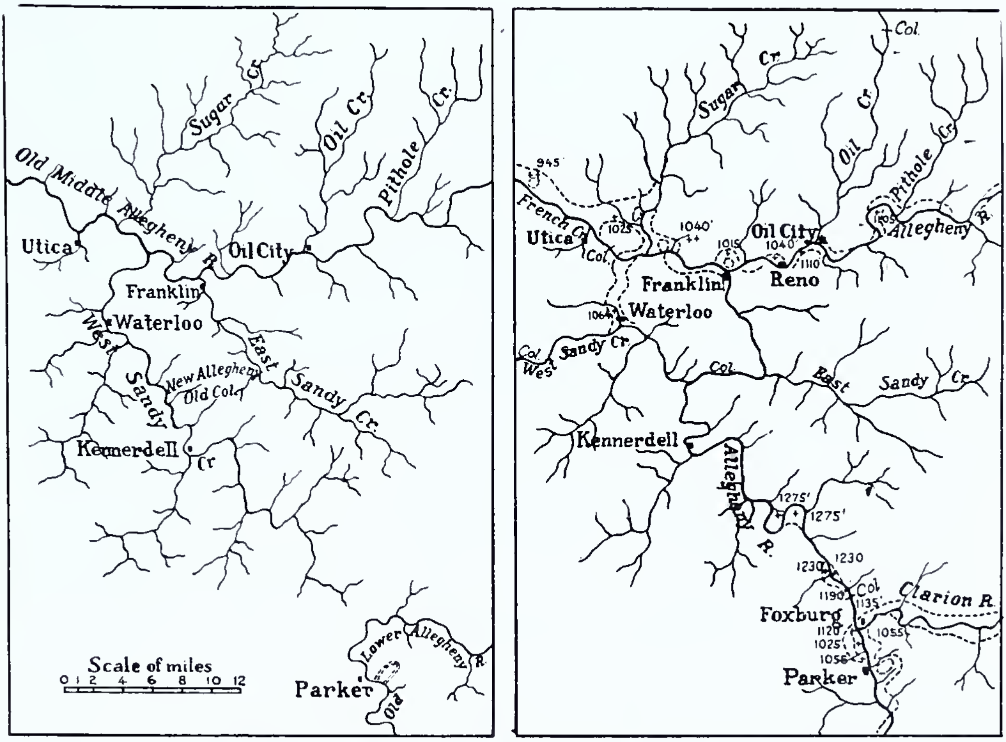

Figure 78. Probable preglacial drainage of the Oil City-Franklin region compared with the present drainage, as worked out by Leverett.

northwestern section the reader is referred to that volume which is available in some larger libraries.

Details such as shown in Figure 78 have been, or will be worked out for all of this area. Suffice to say that there are a hundred unsettled problems that should prove attractive to local students who have the time and inclination for collecting well records in order to determine the exact position of bedrock under the present surface.

Figure 79. A former lake nearly changed to a swamp as the result of filling, Edinboro, Erie County.

Figure 80. Glacial till lying on bedrock, shore of Lake Erie.

Nine lakes and a large number of swamps form a second feature of this part of the State. These lakes, like those in the northeast corner of the State, are the result of the irregular deposits of glacial till or morainic stuff. Conneaut Lake is perhaps typical of these lakes (see Figure 7). The swamps are former lakes now filled up with sediments and vegetable growth.

A third major feature is the succession of lake beaches on the shore of Lake Erie. During the last retreat of the glacier the St. Lawrence outlet was closed by ice and the waters of a lake along the ice front were raised and held above the present lake level long enough to carve an escarpment and lake bottom. Later, as the ice retreated, new and lower outlets were opened, and the subsiding lake formed other beaches at lower levels. Figure 81 shows the lines of three of these beaches, made by the same body of water but at successively lower levels, called Lake Maumee, Lake Whittlesey, and Lake Warren.

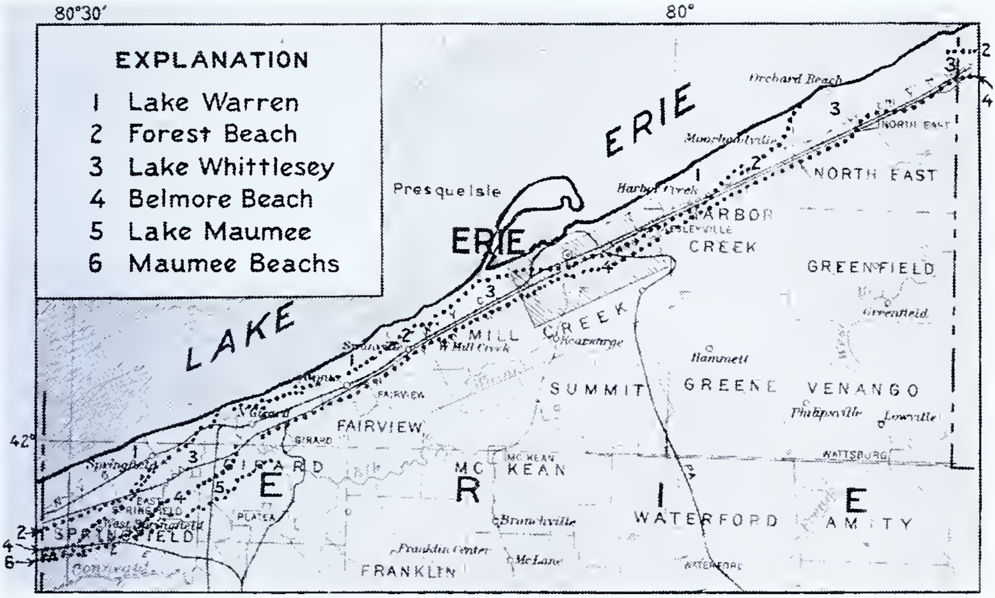

Figure 81. Sketch map showing lake beaches facing Lake Erie in Erie County.

The oldest beach, that of Lake Maumee, extends only a short distance into the western part of the county at an altitude of 770 feet. This lake covered a large area across northern Ohio and found outlet down the Wabash River to the Ohio. When Lake Whittlesey built its beach the ice front is believed to have stood about at Buffalo, and water at this lower level found outlet by way of Lake Saginaw and the Grand River to Lake Michigan and thence southwest. In Erie County this beach runs about parallel with the shore, passing through East Springfield, just north of Girard and Fairview, and through the southern part of Erie and the northern part of the village of Northeast. The elevation of this beach is 746 feet at the Ohio-Pennsylvania line, 748 feet near East Springfield, 752 feet four miles farther east, 765 feet at Swanville, 772 feet at Erie, and 778 feet at Northeast. These changes of elevation are due to post-glacial differential uplift of the land. There is a rise of about 150 feet between the Ohio-Pennsylvania line and Marilla, New York, in a direct distance of not more than 125 miles.

The third beach is that of glacial Lake Warren. The ice is believed to have been farther north, covering the western end of Lake Ontario,

and having its front at Lockport and south of Rochester. Like Lake Whittlesey, the shore of Lake Warren shows marked differential uplift in passing eastward from the Ohio-Pennsylvania line. At the

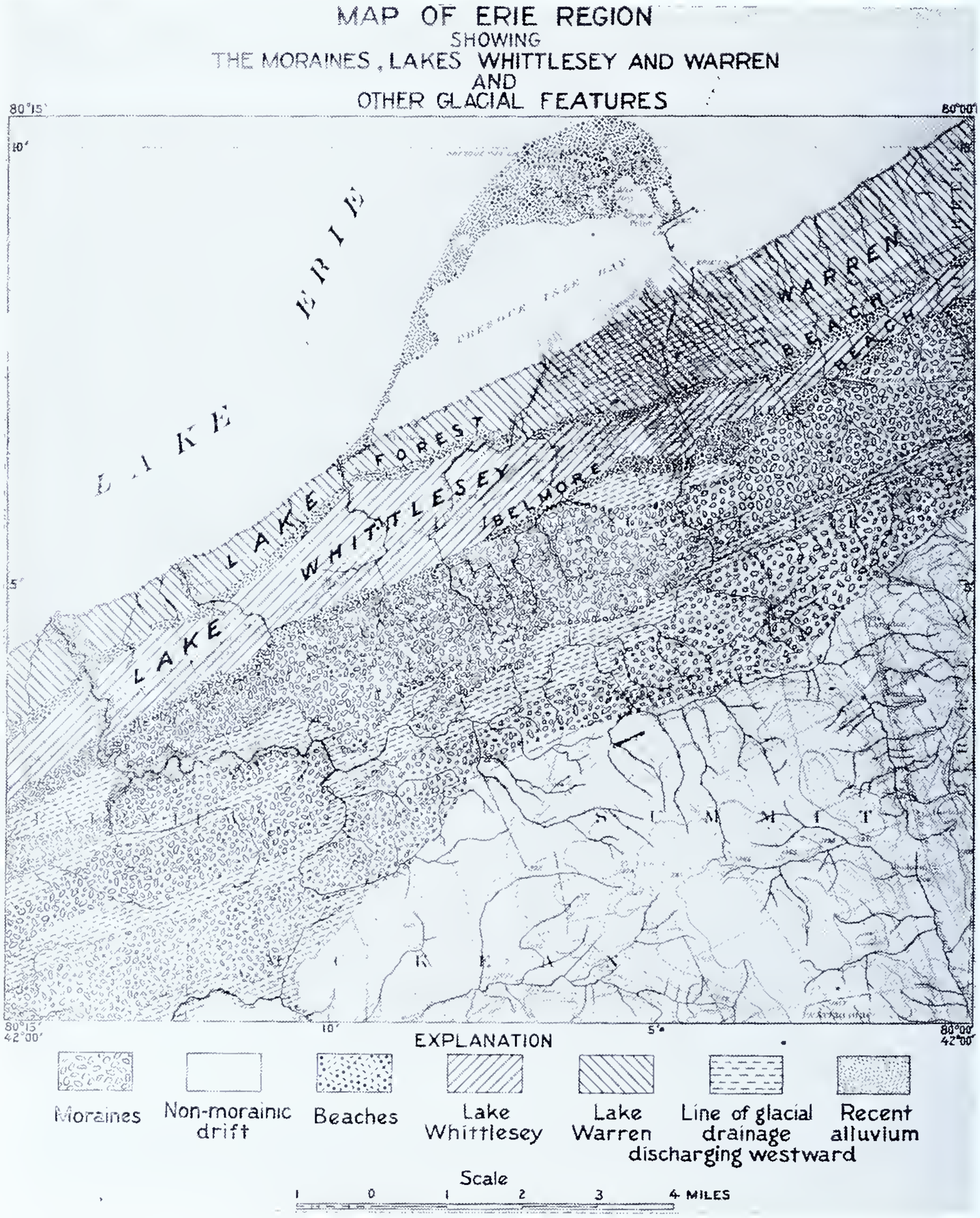

Figure 82. Erie topographic sheet showing surface features, especially the moraines, old lake shores and bottoms.

State line the upper beach stands about 700 feet A. T., and a lower one representing a slight retreat of the ice stands at 678 feet. At Westfield, New York, the upper beach has risen to 742 feet and the lower one at 717 feet, with a third beach at 705 to 707 feet A. T. (See Figure 3).

A fourth interesting feature of this region consists of the so-called gulfs. The scouring out of the lake basin by glacial ice left the

northward-flowing streams well above the present lake surface. In lowering their channels to grade these streams have cut steep-banked ravines or "gulfs" across the edges of the several lake benches as shown in Figure 4.

Illinoian Drift in Northwestern Pennsylvania

Deposits outside the Wisconsin border have long been recognized in western Pennsylvania. Lewis and Wright called them "the fringe" and ascribed them to a temporary extension of Wisconsin ice. However, they present evidence of so much greater age than Wisconsin as to warrant their assignment to Illinoian or earlier time. The exposed Illinoian drift is only 2 or 3 miles wide in Butler County, but widens to 6 or 8 miles in southern Venango County, lying along the bluff of the Allegheny from Kennerdell to near Franklin; then the line crosses east of the river for a few miles, turns west of Oil Creek and crosses between Rouseville and Petroleum Center, passing Pleasantville into Warren County. There it turns northward about 3 miles west of Tidioute and follows the southeast side of Broken Straw Valley to Youngsville; thence eastward on the north side of Allegheny River to north of Warren; and thence with a northward course to New York State. This drift has a greatest exposed width in northwestern Pennsylvania of only about 15 miles, with an average width of about 10 miles.

The Illinoian drift is rather thin on the uplands, usually between 10 and 15 feet, but in places in the valleys is more than 100 feet thick. It is generally so nearly continuous as to be mapped without difficulty to within a mile or two of its limit. This comparative thinness is in contrast with a great volume of valley trains connected with it which extend a long distance down the valleys. This drift shows markedly deeper oxidation than the Wisconsin, the oxidized zone being 30 feet or more in depth, and its surface boulders are much more weathered. The generally loose texture of the till may account for its deeply oxidized condition. Locally the drift surface shows a scarcity of boulders, but elsewhere they are conspicuous, up to 3 feet in diameter, with a fair number of crystalline rocks of Canadian derivation. A kame was noted west of Oil Creek 20 to 25 feet high and 60 feet in diameter.

Illinoian glacial drainage. From Steamburg, New York to Kennerdell, the Allegheny Valley received the outwash from Illinoian ice deposited as a valley train. The filling has an altitude of 1,460 to 1,480 feet at Steamburg, 1,380 feet at Warren, 1,280 feet near Tidioute, 1,240 feet at Oil City, 1,200 feet at Kennerdell, 1,150 feet at the mouth of the Clarion, 1,080 feet at the mouth of Red Bank, 1,040 feet near the mouth of Kiskiminetas, 1,012 feet at the mouth of the Allegheny, about 960 feet at the mouth of Beaver River, and but a little above 900 feet at East Liverpool, Ohio. There are a number of abandoned loops on the Allegheny filled largely with clay, usually lower than the filling in the main channel. On the main stream the filling appears to have been heavier and in places 30 feet higher on the inner curve than on the outer curve. It has been estimated that the Illinoian deposits had a depth of 70 feet and a width of .7 of a mile in the valley below Kennerdell where the stream was entirely outside the

Figure 83. Terrace deposit at Natrona. Photo by H. H. Hughes.

limits of the Illinoian ice sheet. In the Ohio Valley the filling probably had a similar depth and an average width of less than a mile. In general the deposits reached a height of about 200 feet above the river.

Illinoian ponding in the Monongahela basin. It appears that Illinoian waters had a ponded level of fully 1,000 feet at the junction of the Allegheny and Monongahela rivers, the ponding reaching as far up as Morgantown, where the evidence of ponding seems to be

Figure 84. Gravel below silt at 900 feet A. T., 200 feet above drainage, above Pennsylvania Railroad tracks at South Millvale Avenue, Pittsburgh.

slightly below 1,000 feet. In the lower valley of the Monongahela the rock floor of the meanders of that stream would have been about 900 feet A .T., with deposits of river gravel reaching about 920 feet, and silt up to 940 feet and there appears to have been surprisingly little grade between Morgantown and the mouth of the river, possibly due to later differential movement of the earth's crust. The "East Liberty channel" in the city of Pittsburgh is characteristic of these abandoned meandering channels. Like the other channels it carries river rubble and sandy material laid down by the river, overlain by a clay deposit laid down in ponded waters. Water from the Allegheny flowed through gaps in the north rim of the channel and brought in a certain amount of glacial gravel.

Early Glacial Deposits in Western Pennsylvania

Deposits of pre-Illinoian age are very scanty in western Pennsylvania. They are chiefly gravel along lines of glacial drainage, though conspicuous deposits occur near Clarendon, Warren County. The headwaters of the Tionesta originally flowed northward past Warren. The evidence indicates that pre-Illinoian ice closed the old outlet near Clarendon and turned these waters southward into what is now the lower Tionesta. The valley trains mostly have been removed along Tionesta Creek.

Early glacial gravels with deeply weathered granite pebbles occur in the northeastern part of Warren. They are overlain by fresher gravels of Illinoian age. E. H. Williams found a nugget of native copper in these lower beds. As the Illinoian ice came into northwestern Pennsylvania from the northeast, this points to the earlier ice having come from the northwest if it is assumed that the copper came from the Keweenaw peninsula. The evidence is not conclusive.

Glacial deposits on both sides of the Allegheny near Tidioute at just below 1,400 feet are very coarse and appear to be the head of a valley train from an ice sheet that covered the valley to Cobham. The early ice appears to have reached Allegheny Valley as far south as Kennerdell, and in places to have extended beyond the valley. Below Venango County evidences of pre-Illinoian ice are meager and not always trustworthy. In the Franklin, Hilliards, and Foxburg quadrangles early gravels have not been distinguished from the Illinoian gravels. In the Kittanning and Freeport quadrangles gravel has been noted at several places at levels 40 to 60 feet above the Illinoian train. This gravel reaches an altitude of 1,160 to 1,180 feet near East Brady, 1,080 feet near the mouth of Red Bank Creek, 1,100 feet on the east bluff at the mouth of the Kiskiminetas. In the north part of Freeport it stands above 1,080 feet, as well as at a cemetery 3 miles below Freeport. As these deposits contain granite pebbles there is little doubt of their glacial derivation. Pebbles are usually small and deeply weathered. The deposits are between 20 and 40 feet thick. Similar patches of gravel are found farther down the valley at higher altitude than the Illinoian gravel filling, as near the south edge of the New Kensington quadrangle, 1½ miles west of Verona, on a flat-topped area 1,040 feet in altitude. This is about 50 feet above the Illinoian gravel. Deeply weathered gravels occur at Valley Camp between 1,020 and 1,040 feet; also back of Coraopolis where a hill at 1,000

feet is capped with gravel containing granite pebbles. Similar gravel patches above the Illinoian appear on the Beaver River and on the Ohio where it leaves Pennsylvania, and as far down as Bellaire, Ohio.

Abandoned early Quaternary channels. From the above data it appears that the upper Ohio acquired a southward discharge very early, and that at Bellaire and Wheeling this discharge was flowing fully 350 feet above the present river. It had formerly been assumed that the southward discharge was continuous from that time on. However, between East Liverpool and the Ohio-Pennsylvania line, the physiography suggests that the Ohio returned to its northern outlet after the retreat of the earliest ice and did not become permanently diverted southward until Illinoian time. East of East Liverpool (see Fig. 85) are hilltops at 1,020 feet covered with glacial gravel. Around

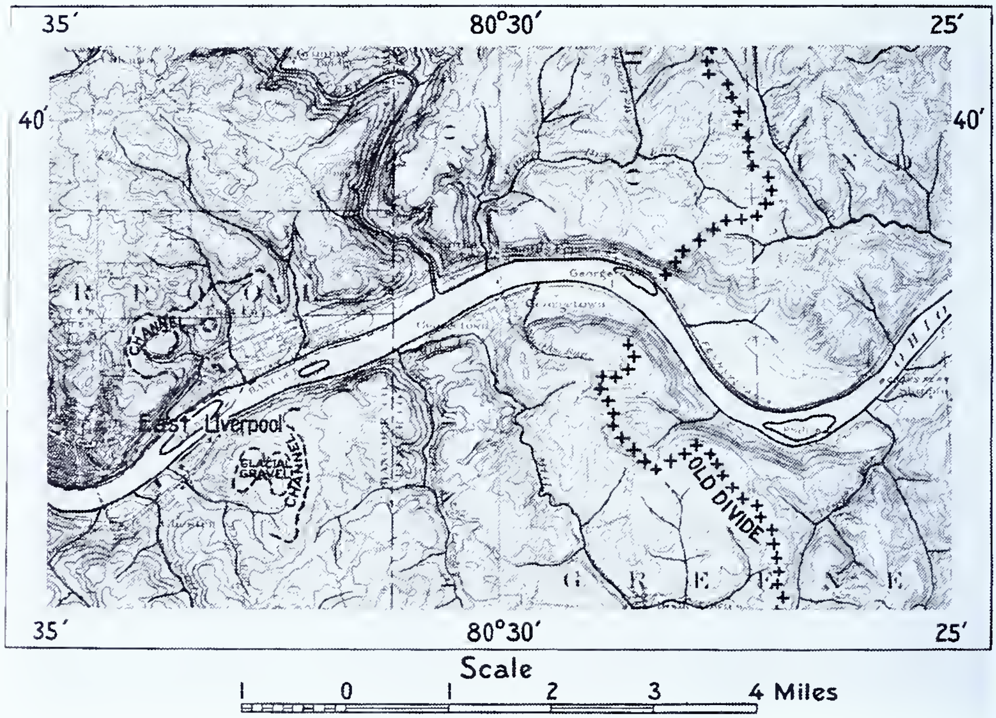

Figure 85. Topographic map showing old divide east of Georgetown, Pennsylvania, and old channels east of East Liverpool, Ohio.

these hilltops at a lower level run channels 300 feet above the river, apparently, though not certainly, of later date. These channels are too small to have carried the Ohio. They are, therefore, interpreted as the channel of a small stream that flowed northward along the present course of the Ohio to below East Liverpool, swinging around through the channels shown on the map and thence northward by way of the Little Beaver (reversed) to the old channel up the Beaver Valley.

These fragmentary channels are above the level of the Illinoian gravel at the mouth of the Beaver as well as at East Liverpool. It is possible that these channels antedate the early glaciation represented by the gravel-covered hilltop at 1,020 feet. The final solution must await further study.

Early Quaternary nonglacial deposits. Certain terraces on streams flowing from areas not covered by the ice seem to lie above the deposits of Illinoian age and are credited to the early Quaternary. Some of the loops of the Monongahela appear to have been abandoned before the Illinoian ice invasion. Clay and sandy deposits thought to be of early Quaternary age, have been traced southward on the Monongahela to Clarksburg and Fairmount, W. Va., where they have an upper limit of 1,040 to 1,050 feet. I. C. White ascribed this clay to ponding and thought the ponding might have reached 1,100 feet and to have discharged westward by a col, such as that at Salem, West Virginia. White called this pond Lake Monongahela. Illinoian ponding appears to have reached only between 980 and 1,000 feet A. T. at Morgantown.

Farther down the Monongahela, pebbles appear at many places up to 1,040 feet in elevation; as back of Dilliner, between Dilliner and New Geneva, near Mapletown, at Masontown, Big Run, Carmichaels, and 3 or 4 miles west of Brownsville, at 1,020 feet. Near-by clay over cobbley deposits at 960 feet is referred to the Illinoian. Farther downstream all the deposits appear to be of Illinoian age. Somewhat similar deposits are found on the Youghiogheny.

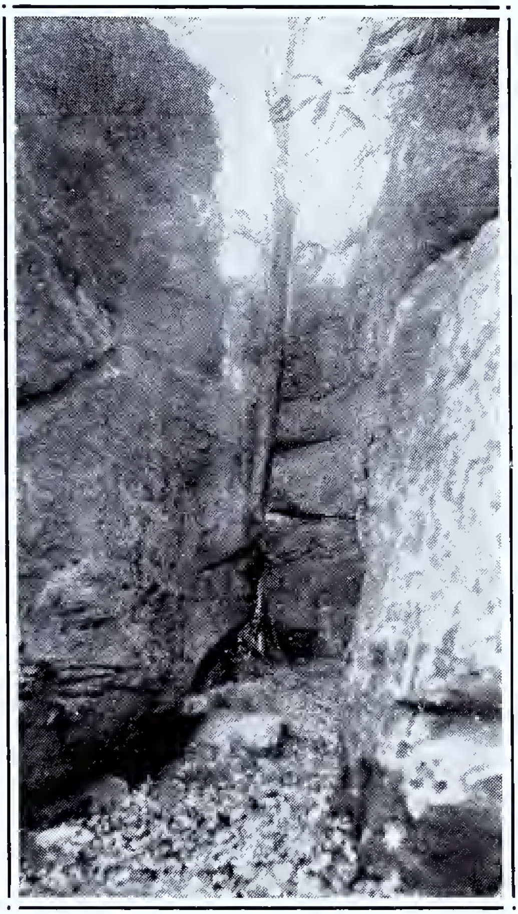

Figure 86. Bilgers rocks (Homewood sandstone) formed by the downhill sliding and separation along vertical joint planes of a massive bed of sandstone. Photo by R. W. Stone.

Rock cities. At many places in the State large blocks of massive rock have been displaced from the parent ledge and lie strewn over the surface. Huge blocks of stone separated by narrow passages or joints, invite exploration and give the appearance of the masonry of a city in ruins. These have been called rock cities.

Such a rock city occurs on the west bank of Bloom Run, 2 miles northeast of Grampian, Clearfield County. Here a massive bed of sandstone, 30 feet or more thick, with a slight east dip and underlain by a bed of clay, has slid slightly toward the valley of Bloom Run with the result that cracks and passages have formed where the sandstone blocks have separated along the vertical joint planes. In places the movement has been small, leaving narrow passages that suggest footpaths between adjoining buildings. In other places, greater movement has left more or less rectangular spaces or rooms between the blocks from which there appears to be no outlet. Examination, however, is likely to reveal another narrow passage leading possibly to another room and so on for some distance. These rock cities make excellent habitats for bear and other wild life of the usually wilderness region in which they occur.

At Eagles Mere is a similar rock city on a very small scale; and also across the line in New York south of Olean is one that has long been famous. Among others in this State is one called Pike's Rocks in Sugar Grove Township, Warren County, and another halfway between Lottsville and Wrightville at Panama where the sandstone is 69 feet thick, and in many other places in that region; also in Heath Township, northern Jefferson County, where the Pottsville sandstones make a succession of rock cities, and in Jackson Township, Potter County.

Figure 87. "Blue Rocks" near Lenhartsville, Berks County. Photo by Bradford Willard.

Devil's race courses. Gravity and alternate freezing and thawing cause rock accumulations on the surface to move slowly by creep to lower areas. Sometimes due to the shape of the surface, this assumes the form of a rock stream or rock glacier. This material, usually large boulders of sandstone or trap rock, may accumulate in a central flat area and have a surface so rough because of the size of the blocks that it is difficult to walk over. "Blue Rocks" near Lenhartsville, Berks County, is shown in Figure 87. Similar accumulations of large rocks over which, according to local legend, the Devil is supposed to have delighted to exercise, occur on top of Third Mountain at the point where it divides to form Sharp and Stony Mountain. Another devil's race course occurs in South Mountain, 5 miles east of Waynesboro, Franklin County, composed of Cambrian quartzite stripped of soil, as described by Stose.*

Figure 88. "Devil's race course," 5 miles east of Waynesboro, Franklin County. Photo by F. J. W. Horich.

Ringing rocks. In a number of places in the State somewhat similar accumulations of trap rock have the added attraction that some large boulders ring almost like a bell when struck with a hammer. Only those that are supported by small contacts at three or less points will ring. These rocks are usually dense and, therefore, when so supported vibrate with some freedom. A ringing rock removed from its natural place and supported by chains or otherwise, as has been done at the

*Stose, Geo. W., and Bascom, F., U. S. Geol. Survey Atlas, Fairfield-Gettysburg folio, No. 225, 1929.

Figure 89. Ringing rocks in Bridgeton Township, east of Kintnersville, Bucks County.

Figure 90. Delaware Water Gap; combining in one view a fine display of bedded rocks (basal Silurian); of rock structure or lie (late Carboniferous folding); of differential erosion (valleys either side etched out leaving resistant sandstone as mountain) and of river history (river formerly flowed on plane overlying present crest of mountain, then lowlying but since raised and destroyed, though still reflected in the nearly level character of the mountain top.

Philadelphia Academy of Science, will ring when struck by a hammer quite as well as in nature.

Ice caves. At several places in this State, notably south of Coudersport, Potter County, conditions exist that result in the production of ice in midsummer. The usual conditions are a rock floe or accumulation of blocks 20 or more feet deep and covered with a mat of vegetation. During the winter cold air settles into the open spaces between the blocks and is stored there, probably along with ice. In the summer this cold air makes its way out and forms ice at the point of exit. The air movement depends more or less on the outside temperature, so that the hotter the day the more active the movement of cold air and the larger amount of ice produced.

A natural cavity in a rock floe that contains ice in summer is near Aitch, Huntingdon County, along an abandoned railroad grade in State Forest land. Others are reported at Riverview opposite Farrandsville, 6 miles west of Lock Haven, and near State Forest camp ground between Spruce Creek and Pine Grove Mills, Huntingdon County.